THE
BOTANICAL GAZETTE

EDITORS:

JOHN MERLE COULTER AND CHARLES REID BARNES

VOLUME XLII

JULY—DECEMBER, 1906

WITH THIRTY PLATES AND NINETY-FIVE FIGURES

CHICAGO, ILLINOIS

PUBLISHED BY THE UNIVERSITY OF CHICAGO

1906

PRINTED AT
The University of Chicago Press
CHICAGO

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DATES OF PUBLICATION

No. 1, July 28; No. 2, August 30; No. 3, October 2; No. 4; October 23; No. 5, November 30; No. 6, Dec. 22.

ERRATA

Vol. 41: p. 394, legend, for *fig. 3*, read *fig. 4*.
P. 16, line 17, for 15^{cm} read 25^{cm}.
P. 17, line 1, for 15^{cm} read 25^{cm}.
P. 21, line 3, for 1889^{m} read 2000^{m}.
P. 32, line 11, for (*fig. 6*) read (*fig. 7*).
P. 66, line 20, for WEIS MAN read WEISMANN.
P. 141, line 15, add Nov. 15.
P. 164, line 11 from bottom, for concluding read including.
P. 165, line 10, for dioecious read monoecious.
P. 308, line 10, for some read deeper colonies.
P. 308, line 20, for boullion read bouillon.
P. 312, line 15, for ROBERTSON read ROBINSON.

VOLUME XLII NUMBER 1

BOTANICAL GAZETTE

JULY, 1906

ON CRETACEOUS PITYOXYLA.[1]

E. C. JEFFREY AND M. A. CHRYSLER.

(WITH PLATES I AND II)

IN a recent publication Dr. ARTHUR HOLLICK[2] has described the discovery of amber in the Raritan formation of the Middle Cretaceous, at Kreischerville, Staten Island. The amber in question occurs in largest quantity "in a stratum or bed, characterized by layers and closely packed masses of vegetable débris, consisting of leaves, twigs, and fragments of lignite and charred wood." Lignite occurring in association with amber at Cape Sable, Magothy River, Anne Arundel County, Maryland, collected by Professor A. BIBBINS of the Woman's College, Baltimore, and of somewhat similar geological horizon, has recently been determined by Dr. F. H. KNOWLTON[3] of the United States Geological Survey as a new species of Cupressinoxylon. It appeared desirable to one of us that the lignites associated with the Kreischerville deposits of amber should be subjected to microscopic examination, in view of the possibility that the succiniferous ones might also turn out to belong to an extinct species of Sequoia (Cupressinoxylon). On communicating with Dr. HOLLICK in regard to this possibility, he very kindly consented to a combined visit to the beds at Kreischerville, for the purpose of securing authentic specimens of the succiniferous and other lignites. On April 18, 1905, we examined together the various

[1] Contributions from the Phanerogamic Laboratories of Harvard University, No. 5.

[2] Amer. Nat. 39:137–145. 1905. Contributions from the New York Botanical Garden, No. 64.

[3] American amber-producing tree. Science N. S. 3:582–584. *figs. 1–4*. 1896.

excavations in the Cretaceous clays at Kreischerville, particularly that known as the Androvette pit, where the largest quantities of amber have been found. We were fortunate enough on this occasion to secure a large quantity of lignites, including several fragments of some size, showing the amber *in situ*. On a subsequent visit, in the following autumn a further supply of material was secured, including some admirably preserved Pityoxylon from a newly opened excavation known as the Drummond pit.

The lignites gathered at Kreischerville belong to at least three genera: Araucarioxylon, Cupressinoxylon, and Pityoxylon. Of these only the last proved to be succiniferous. The first two genera mentioned represent several species and present features of very considerable interest, but it is not our intention to discuss them further here. The pityoxyloid lignite containing masses of amber was found in the form of large pieces from the various excavations at Kreischerville, as well as in smaller fragments occurring in the amber-bearing strata themselves, at the Androvette pit, as described by Dr. HOLLICK (*l. c.*). The amber enclosed in lignite appears both in the translucent shining condition and in the dull ochraceous modification. In the latter state it is particularly conspicuous on account of the contrast in color with the black lignite, and may be made out not only in the form of pockets and nuggets, but also as fine yellow threads or streaks corresponding to the normal resin passages of the wood. Unfortunately the state of preservation of most of the succiniferous lignites left something to be desired. In the Drummond and Androvette pits, however, were found a number of partially charred, and, as a consequence, exquisitely preserved Pityoxyla, which were apparently specifically identical with or at any rate closely allied to the actually succiniferous fragments of Pityoxylon. It has been thought advisable to defer the description of the amber-containing lignites until a greater quantity of material should be accumulated, which might not only be better preserved, but might also throw some light on the conditions leading to the formation of amber. The partially charred lignites belonging to the genus *Pityoxylon* Kraus appear, nevertheless, worthy of immediate investigation, both because they show features of considerable phylogenetic interest, and because the genus Pity-

oxylon is considered by some paleobotanists not to antedate the Tertiary.[4]

The specimens of Pityoxylon, which have served as the material for the present investigation, consist for the most part of cylindrical fragments, which are sometimes as thick as 10^{cm} and often twice as long. Most of them however are of smaller size. Where the pieces are cylindrical they generally include the pith in a good state of preservation, a feature of some importance in connection with their diagnosis. It is not possible to state absolutely from the nature of the specimens whether they represent smaller branches or merely the core of larger axes from which the external layers have been burned off. From the ordinarily tylosed condition of the resin canals, it may be inferred with a strong degree of probability that the latter supposition is more likely to be correct. Angular fragments showing annual rings with a large radius of curvature permit a study of the structure of the older wood. Although at least two different species of fascicles of pine needles and at least as many species of cone scales of Pinus, all in an admirable condition of preservation, have been found in association with the Pityoxyla from the Androvette pit, it has not been possible to distinguish in these lignites more than one type of wood structure. The material in this respect presents an interesting parallel to the condition found by CONWENTZ[5] to exist in the Pityoxyla of the Eocene or early Oligocene, which bear the well-known Baltic amber; for this author declares that he is unable in the vast variety of fossil succiniferous woods which have passed under his inspection to diagnose more than a single species. The absence of clearly marked criteria for the separation of species on the basis of wood structure is not surprising, since even in the case of living pines it is difficult to do more than segregate the various species into larger groups or sections on the characters offered by the wood.

Fig. 1 shows the structural features of a transverse section of a slightly flattened branch about 5^{cm} in thickness in its greatest diameter, and showing more or less distinctly about twenty annual

[4] *Cf.* GOTHAN, Zur Anatomie lebender u. fossiler Gymnospermen-Hölzer 88. Herausgeb. von der Königlich Preussischen Geologischen Landesanstalt und Bergakademie. pp. 108. Berlin, 1905.

[5] Monographie der Baltischen Bernsteinbäume. Danzig, 1890.

rings. It is to be observed from the photograph that the annual rings are not as strongly marked as they are in pines of the present day. This feature is due to the less pronounced thickening of the tracheids of the summer wood. There are no parenchyma cells present in the wood except those which surround the resin canals. The rays are strongly marked on account of the resinous character of their contents, a feature of difference from modern pines, where as a rule the ray-cells are quite free from the dark brown secretion which is characteristic of the resiniferous cells in the Cupressineae and in the genera Cedrus and Tsuga among the Abietineae. The resin canals show a tendency to become aggregated in clusters. They may be almost absent in one or more annual rings and correspondingly abundant in others. The resin ducts are surrounded by highly resiniferous cells and appear not to be confined to any special region of the annual ring. On the left of the figure is to be seen a resin canal occluded by tyloses.

Fig. 2 shows a section of the same branch which includes a portion of the pith. The medullary cells are filled with dark brown contents. Sclerified cells are quite absent in the pith. To the right of the photograph a process passes off from the medulla, which is the pith of a small branch, in all probability a brachyblast or short shoot. In the wood immediately adjoining the pith may be seen a number of resin canals, closely filled with tyloses. The position of these resin canals in relation to the pith is that found among living species of Pinus, in the hard pines (*Scleropitys* auct.), in which the resin canals also abut on the pith, in some cases actually occurring in the primary wood, in contrast to the soft pines (*Malacopitys* auct.), where the resin ducts are somewhat remote from the pith and never occur in the primary wood. The annual rings are generally less well marked in proximity to the medulla than in the more external part of the wood.

Fig. 3 is a longitudinal radial view of the wood of the same specimen illustrated in the two preceding photographs. The section shows a single vertical and several anastomosing horizontal resin canals, all quite filled with tyloses. A careful inspection indicates that the wood is made up of tracheids, which are provided with a single vertical row of radial bordered pits.

Fig. 4 shows the structure of the wood in the same specimen, as seen in tangential section under a low magnification. The rays are of the two kinds found in *Pityoxylon* Kraus, namely, linear and fusiform.

Fig. 5 shows a tangential view of part of the same section, more highly magnified. In this view the radial pits of the tracheids may be seen in profile, and on the left a face view of a few tangential pits. In some of the rays dark contents may be made out in the cells, which have partially shrunk away from walls. This is apparently of the same nature as the dark brown material found in the resin cells of certain living conifers. The interesting fact to be noted is that the resin occurs equally in the marginal and in the central cells of the ray. This feature may be clearly distinguished in two of the rays on the lower left portion of the photograph. In living pines resin never occurs in the marginal cells of the ray, which, as is well known, are not true parenchymatous cells, but are of a tracheary nature. They are in fact variously described as marginal tracheids, horizontal tracheids, and tracheidal cells.

Fig. 6 shows another portion of the same section as that represented in *fig. 4*, on the same scale of magnification as *fig. 5*. This figure shows very clearly the occurrence of tangential pits, which are confined to the autumnal tracheids as in certain living species of Pinus. In *figs. 5* and *6* may be seen fusiform rays containing horizontal resin canals occluded by tyloses.

Fig. 7 represents a transverse section, under high power of magnification, of the autumnal wood of a specimen showing annual rings with a large radius of curvature. The elements are much larger in this instance, as is the rule in the older wood of the Coniferales in general. The tangential pits of the autumnal wood can be very clearly made out. We have found no specimen of Pityoxylon from the Kreischerville deposits in which the tangential pitting of the autumnal tracheids is not a marked feature. CONWENTZ has pointed out that this feature is also present in the autumnal wood of the Baltic amber-producing trees (*l. c.*, p. 21).

It will be inferred from the above description that the Cretaceous Pityoxyla just described differ in several features from the woods of any modern or even Tertiary species of Pinus. The leafy short-

shoots found in intimate association with the Pityoxylon here described, which unquestionably belong to the genus Pinus in the narrower sense, have the double bundle which is characteristic of the hard pines,[6] as has been learned by one of us from a microscopic investigation of their structure. They are also provided with the persistent foliar sheaths, which are a striking feature of the hard or pitch pines in contrast to the soft pines, which have deciduous sheaths. All the numerous cone scales found in intimate association with the wood, illustrated in our *figs. 1–7*, are equally characteristic of the hard pines, for they have the thickened apophysis and median umbo, which are unfailing features of that group. In the case of our Pityoxylon, however, we find universally present the tangential pits of the autumnal tracheids, which are characteristic of the existing soft pines.[7] STRASBURGER, however, states that he has found tangential pits to be present in the autumnal wood of *Pinus canariensis* and *Pinus rigida*. MAYR[8] has also called attention to the occasional occurrence of tangential pits in the autumnal wood of one group of the hard pines. This feature has also not escaped the notice of CONWENTZ. One of us has observed the very frequent occurrence of tangential pits in the autumnal wood of the *cone* in various species of hard pines, where they are quite absent in the vegetative wood. This is the case, for example, in the woody axis of the cone of *P. Pinaster*, the vegetative wood of which is described by KRAUS[9] as having no tangential pits. *P. palustris* too, although it is a characteristic hard pine, in the absence of tangential pits from its autumnal wood,[10] possesses these in great abundance in the autumnal wood of its cone, in both the annual rings present. These two examples will suffice to illustrate the fact that tangential autumnal pits, such as are ordinarily absent in the wood of hard pines, are generally present in their *cones*. It may be inferred from the mode of their occurrence that tangential

6 COULTER and ROSE, Synopsis of North American pines based on leaf-anatomy. BOT. GAZETTE 11:256, 302. 1886.

7 PENHALLOW, Anatomy of the Coniferales. Amer. Nat. 38:243. 1904. STRASBURGER, Ueber den Bau und die Verrichtungen der Leitungsbahnen in den Pflanzen.

8 Waldungen Nordamerikas.

9 Beiträge zur Kenntniss fossiler Hölzer, p. 25.

10 PENHALLOW, *loc. cit.*, :04.

bordered pits in the tracheids of the hard pines are an ancestral feature. It is accordingly not surprising to find them more commonly present in older types of hard pines than those now living. CONWENTZ in his admirably accurate and thorough account of the wood of *Pinus succinifera* notes their invariable presence in this species, which on account of its denticulate marginal ray-tracheids must be considered to belong to the hard pines. As has already been pointed out, the structure of the associated leaf fascicles and cone scales leads to the conclusion that the Cretaceous Pityoxylon under discussion belongs also to a hard pine. The mode of occurrence of the resin canals in the medullary crown, which is illustrated in *fig. 2*, is also that which is characteristic of the hard pines.

The most reliable feature of difference separating histologically the hard pines from the soft pines is the occurrence of denticulate marginal tracheids in the former group. In the soft pines the marginal tracheids are entirely without denticulations. In our Pityoxylon, as has been shown above, marginal tracheids of any kind are quite absent; so that it is not possible on this feature to diagnose the affinity of our material with either of the two main groups of pines still living. It is of interest to note that the Cretaceous Pityoxylon under discussion has the general structure of the rays found in Abies or Pseudolarix, with the wood structure found in Tertiary and modern species of Pinus. There can be little doubt that in the peculiar structure of the rays we have to do with an ancestral feature; for if we take for example a modern species of Pinus, in which the marginal tracheids are well developed even in the first annual ring, such as *P. palustris*, we find the marginal tracheary cells entirely absent in most of the rays of the two annual rings of the female cone. It is well known that in many of the modern species of Pinus the marginal tracheary ray-cells do not appear until the branch is from one to several years old. The same feature, if one may judge from CONWENTZ' description, was also present to an even more marked degree in the Baltic amber pines, which are considered by CONWENTZ to belong to the early Oligocene or late Eocene. Another feature of striking resemblance presented by the wood of the *cones* only of existing species of Pinus, to the vegetative woods of Cretaceous Pityoxyla which we have investigated, is the highly

resinous character of the ray-cells. This feature may also be well seen in *P. palustris*, already referred to. The contrast in the contents of the ray-cells as they occur in the wood of the cone or of a vegetative branch is very strongly marked.

It may be inferred that we have overlooked the presence of tracheary marginal cells in the Cretaceous Pityoxyla, which are the subject of the present article. This view cannot however be accepted, as the wood of some of our partially charred specimens is in a perfect condition of preservation, often not even showing the spiral striations which are generally found as a feature of decay in many fossil woods, otherwise well preserved. Moreover, in shallow rays consisting of a single stratum of cells, which in the case of modern species of Pinus are composed entirely of tracheids, the cells are parenchymatous and invariably filled with a dark brown resinous content, which leaves no doubt as to their histological nature. The cells on the margins of the rays in our Pityoxylon are moreover related to the central cells of the rays and to each other by simple pits and not by bordered pits, as is the case with the marginal tracheids. It is obvious that the ray-structure of Pinus underwent a great change in the passage from the Mesozoic to the Tertiary period.

On account of the geographical occurrence of the Pityoxylon, which has just been described, it is called **Pityoxylon statenense.** The diagnosis is as follows:

Transverse.—Annual rings narrow, sometimes not clearly marked; wood parenchyma absent except in the periphery of the resin canals, which may occur in any part of the annual rings and are often stopped with tyloses; rays highly resinous; bordered pits present on the tangential walls of the autumnal tracheids; tracheids about 25 μ in diameter.

Radial.—Radial pits of tracheids about 17 μ in diameter, in a single vertical row, round with a round mouth; pits of the ray-cells about one per tracheid, round or somewhat elliptical, 10 μ in diameter; ray-cells all parenchymatous, very resinous, length from 100 to 120 μ; marginal ray tracheids quite absent.

Tangential.—Rays of two kinds, linear and fusiform, the latter containing resin canals which are surrounded with rather thick-walled parenchyma; resin canals often occluded by tyloses; tangential pits present in the autumn wood.

In addition to the Pityoxylon described above, we have examined another of the same type, which was secured by Dr. ISAAC BOWMAN

from a newly exposed section at Third Cliff, Scituate, Mass. Although there is some question as to the exact geological age of the strata from which it was taken, it is considered desirable to refer to it at the present time on account of the interesting similarity to the species discussed above. Dr. Bowman describes[11] the section from which the material was taken as follows: "The section at Third Cliff shows yellow clays at the base conformably overlain by yellow and white sands and succeeded by a bed of bright red sands with an unconformity at their base. On the eroded edges of the red and white beds are deposited dark glauconitic and lignitic clays and sands. The entire series of beds has a total maximum thickness of 60 or 70 feet and outcrops for half a mile along the cliff face. Absolutely no erratic material occurs either within the beds themselves or along the lines of unconformity." The lignite to be described came from the "lignitic sands and clays" just mentioned.

The material consisted originally of several laminated and badly preserved fragments, together with one larger piece, cubical and about 12^{cm} in its three dimensions. The better-preserved fragment has served as the basis of the following description. As the result of decay and pressure, the lignite has suffered some compression both in the radial and tangential planes. The stress in the radial plane has produced a considerable sinuosity in the course of the wood rays. The annual rings cannot be made out with the naked eye or even with a pocket lens of some degree of magnification.

Fig. 8 shows a magnified portion of a transverse section of this wood. The area of the photograph includes parts of two annual rings. The line of demarcation is very indistinct and runs obliquely a little above the lower third of the photograph. The rays are very dark on account of the highly resinous character of their contents. Two large patches of parenchyma may be seen surrounding two vertical resin canals. The large amount of resiniferous parenchyma about the canals is particularly characteristic of this species. There are no parenchyma cells in the wood other than those surrounding the resin canals. The annual rings have a very slight radius of curvature and are somewhat distorted on account of the compression of the wood, although the elements which compose them are well

[11] Science N. S. **22**:993–994. 1905.

preserved. The lignite under discussion obviously is part of an old stem.

Fig. 9 is a radial view of the wood of the Pityoxylon from the cliffs at Scituate. This view shows the extremely resinous character of the rays, which doubtless is largely responsible for the good preservation of the wood, as, unlike the material of *Pityoxylon statenense*, it has not been charred in any way by fire. The rays are quite without tracheidal marginal cells and in this respect resemble those of the first described species, and differ from the ray vegetative structure found in any modern species of Pinus.

Fig. 10 shows a tangential view of the wood. The rays are obviously of two kinds, namely, linear and fusiform. The former are often very deep, and in this feature present a marked contrast to the first described species of Pityoxylon. The fusiform rays are usually occupied by a horizontal resin canal, the lumen of which is often filled with a dark brown material similar to that found in the surrounding resiniferous cells of the ray. Tyloses have not been found either in the horizontal or the vertical resin canals of this species.

Fig. 11 shows a portion of the same section more highly magnified. The highly resinous character of the rays can clearly be made out. There is one fusiform ray present containing a horizontal resin canal, which is filled with a dark brown material similar to that found in the ray-cells. It may here be stated that in spite of the fact that the cells surrounding the lumina of the horizontal and vertical resin ducts cannot be described accurately as being thick-walled, nevertheless the ducts are never occupied by tyloses.

Fig. 12 shows another tangential view under considerable magnification. This illustrates the fact that in the rays the marginal as well as the central cells contain the same dark brown resin, as has already been referred to in the case of the other Cretaceous Pityoxylon described above. The wood is so well preserved that there can be no question as to the absence of marginal tracheids, such as occur in the rays of living species of Pinus and allied genera. Not only are the marginal cells filled with the same dark resinous material as the other cells of the ray, but they are related radially to each other, as well as to the central cells of the ray, above and below by simple pits.

This species of Pityoxylon is named **Pityoxylon scituatense,** from its place of origin. The diagnosis is as follows:

Transverse.—Annual rings moderately broad, indistinctly marked; resin ducts present, surrounded by a very deep zone of resiniferous parenchyma, without tyloses but sometimes filled with dark resinous contents; wood parenchyma quite absent; rays very dark and resinous; tracheids averaging 39 μ in diameter.

Radial.—Radial pits of the tracheids in a single row with the very oblique narrow mouths forming a cross, diameter of the pits about 20 μ; pits of the ray-cells generally one per tracheid with narrow oblique mouth, about 10 μ in diameter; ray-cells all parenchymatous, average length 340 μ, very resinous; marginal ray-tracheids quite absent.

Tangential.—Rays of two kinds, linear and fusiform, the former often very deep; fusiform rays containing horizontal resin canals, which are always free from tyloses although somewhat thin-walled, both kinds of rays very resinous; tangential pits present in some of the tracheids.

In the two species of Pityoxylon described above, we have to do with woods which resemble those of the existing pines, but which nevertheless differ from them in important particulars. The marginal ray tracheids, which are not only characteristic of Pinus but of the allied genera Picea, Pseudotsuga, and Larix, are quite absent in our two species. The question arises whether it is proper to include them within the genus Pityoxylon, which has recently been stated not to antedate the Tertiary.[12] There is much to be said for such a course. In the case of our *Pityoxylon statenense* there can be no reasonable doubt that we have to do with the wood of a fossil species of Pinus, from the abundant occurrence in intimate association with the lignites of charred remains of cone scales and leaf fascicles of pines. Any doubt as to the identity of these scales and foliar shoots has been removed by a study of their microscopic structure, as well as their external features. Further, one of us has observed from the study of the *cones* of living pines that the features which are characteristic of our fossil woods are exactly those which are found to be distinctive of the wood structure of the cones of the living species of Pinus. There can be little doubt that in the case of the wood of the cones of *Pinus palustris*, for example, the general absence of marginal tracheids, the highly resinous character of the rays, and the abundant presence of tan-

[12] GOTHAN, *l. c.*, p. 88.

gential autumnal pits, all features of difference from the vegetative wood structure of existing hard pines, are ancestral characters, since such characters are wont to linger on in the reproductive axis. Indeed in no other way can the presence of these features in the wood of the cone be explained. It seems inadvisable to invent a new generic name for a fossil wood, which although lacking the marginal ray tracheids, which are characteristic not only of the wood of living pines, but of also Pityoxylon as generally defined, is beyond any reasonable doubt the wood of a Cretaceous pine. We find it difficult to follow GOTHAN (*l. c.*, p. 102) in establishing a new pityoxyloid genus of fossil woods, Pinuxylon, to which is assigned the ligneous characters of the living Pinus in the narrower sense. *Pityoxylon* Kraus seems rather in need of a wider than a narrower interpretation, if it is to include the wood of Pinus of the Cretaceous as well as Tertiary times. In the case of our *Pityoxylon statenense* there can be no reasonable doubt that we have to do with the wood of an extinct Cretaceous pine. It seems on account of its distinctive archaic features, however, inadvisable to name it under Pinus as CONWENTZ has rightly done in the case of the Tertiary *Pinus succinifera*, which is practically identical in its wood structure with modern hard pines. The retention of the genus *Pityoxylon* Kraus appears, for the present at any rate, absolutely essential in view of such cases as that presented by our *Pityoxylon statenense.* The evidence as to *Pityoxylon scituatense* is much less clear, as no cone scales or leaves have been found with it. Since, however, it presents the same general features as *P. statenense*, it may conveniently be included under the same genus.

There is good reason to believe from recent researches[13] that the genus Pinus in essentially its modern form, so far as the external features of the female cones go, existed as far back as the Jurassic. There is even evidence that the two great series of the hard and soft pines existed at this early period so that the geological extension of the genus must have been much more remote. Without considering the evidence for the existence of Abietineae at earlier geological periods than the Tertiary, furnished by impressions of the

[13] FLICHE, P. et ZEILLER, R., Florule portlandienne des environs de Boulogne-sur-Mer. Bull. Soc. Géol. France IV. 4:787–812. 1904.

foliage, etc., there are now definite records, based on internal structure, which carry the group far into the past. KNOWLTON[14] has recently described an abietineous wood from the Jurassic beds of the Black Hills of Dakota which he calls *Pinoxylon dacotense.* It is characterized by the possession of vertical resin canals only, which are numerous and may occur in any part of the clearly marked annual rings. The structure of the tracheids and rays is that of the Abietineae. This author does not mention the presence of marginal ray tracheids, and in view of the fact that he describes the wood as admirably preserved, they probably may be considered to be absent here as in our Cretaceous Pityoxyla.

The *Pityoxylon Conwentzianum* of GOEPPERT from the Carboniferous of Waldenburg,[15] which has often been called in question, has received full confirmation from the description of a similar type of Pityoxylon, *P. chasense*, by PENHALLOW[16] from the Permian of Kansas. In these two species vertical resin canals are said to be absent, although the horizontal canals of the fusiform rays are clearly present. There is, accordingly, every reason to believe that the Abietineae are a very ancient group in their first appearance. In fact, they may be traced geologically quite as far back as the Araucarineae, which it is customary at the present time to regard as the oldest of the Coniferales. That they are not more numerously represented in the Mesozoic and earlier strata is probably entirely a matter of antisepsis, since araucarineous remains are in general much better preserved than are those of the Abietineae, where they are found imbedded together in the same strata. Mention need not be made here of the *Pityoxylon eggense* (Witham) Kraus and *Pityoxylon Hollicki* Knowlton,[17] since both of these appear to have been in a bad state of preservation.

The peculiar structure of the wood of Pinus in the Cretaceous, as distinguished from that found in the case of Tertiary and living pines, probably affords an explanation of the greater vigor of the

14 U. S. Geol. Surv. Ann. Rept. **20**²: 420–422. 1898–1899.

15 GOEPPERT, Revision meiner Arbeiten.

16 North American species of Dadoxylon. Trans. Roy. Soc. Canada II. **6**⁴: 76. 1900.

17 Trans. N. Y. Acad. Sci. **16**: 134–136.

genus under modern conditions. It is generally inferred that genera which flourish under modern conditions cannot be of very ancient origin. This generalization, however, cannot be accepted in the case of Pinus, which, although found actually abundantly throughout the northern hemisphere in from 80 to 90 species, can be traced in obviously allied genera back to the Carboniferous. The appearance of marginal ray tracheids about the beginning of the Tertiary epoch, with the resulting improvement of water-supply, in all probability explains why so comparatively large-leaved a conifer should have been able not only to live on into the modern period, but to flourish as it never had before. Even at the comparatively early epoch of the Baltic amber beds (probably Eocene), there were numerous species present in the somewhat restricted area represented by that formation.

CONCLUSIONS.

1. The woods of certain pines of the Middle Cretaceous of Staten Island differed from those of existing pines (*a*) in the absence of marginal tracheids in the rays; (*b*) in the highly resinous nature of the rays; (*c*) in the association of characteristic features of the hard pines, as exemplified by leaf-fascicles, cone-scales, and structure of the primary wood, with the numerous tangential pits of the autumnal wood which are a feature of the living soft pines.

2. These features of difference from modern pines are probably to be regarded as ancestral, since they persist clearly and strongly in the structure of the wood of the cones of the living species.

3. The appearance of marginal tracheids in the rays of Pinus is comparatively modern and does not in all probability antedate the Tertiary. It probably explains the greater prosperity of the genus in recent times.

4. Another species of Pityoxylon from Scituate, Mass., has been described, which has the general features of the Pityoxyla of Staten Island. It is not possible, however, to refer it definitely to Pinus, nor is its geological horizon settled.

In conclusion we wish to offer our warm thanks to Dr. Hollick for many kindnesses in the matter of securing material.

Harvard University.

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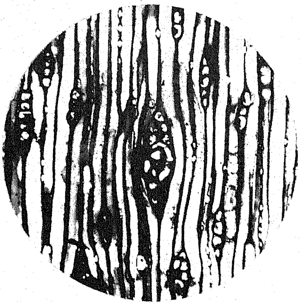

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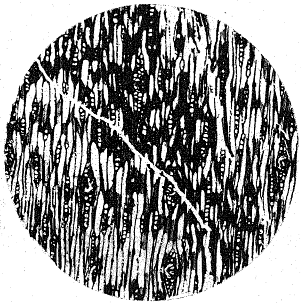

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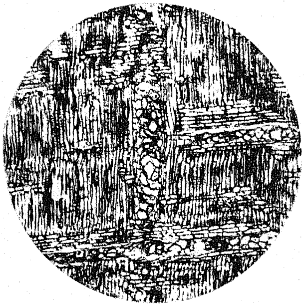

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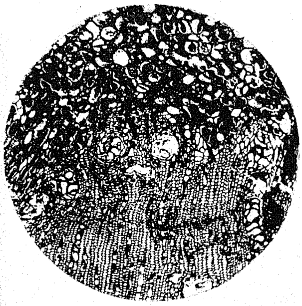

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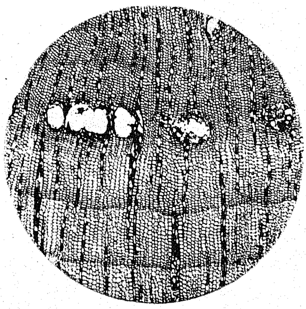

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JEFFREY & CHRYSLER on PITYOXYLA

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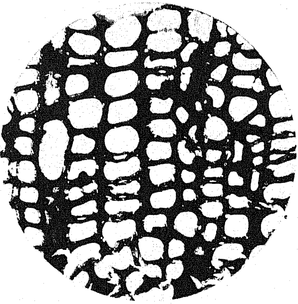

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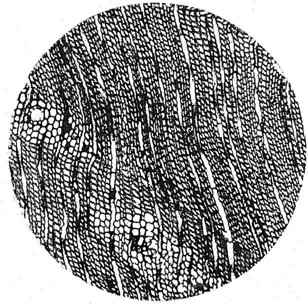

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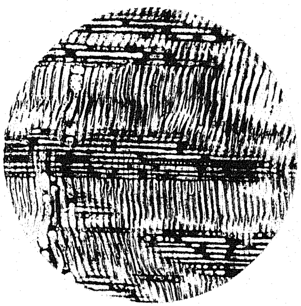

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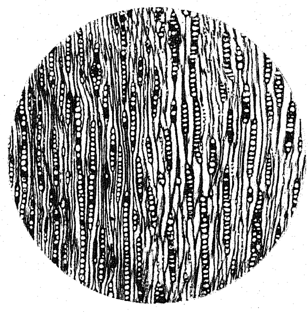

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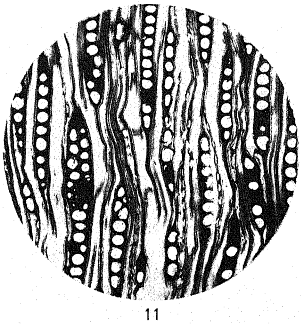

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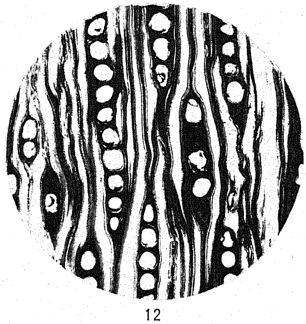

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JEFFREY & CHRYSLER on PITYOXYLA

EXPLANATION OF PLATES I AND II.

PLATE I.

Pityoxylon statenense.

FIG. 1. Transverse section of the wood. ×20.
FIG. 2. Transverse section of the wood near the pith. ×40.
FIG. 3. Radial section. ×60.
FIG. 4. Tangential section. ×60.
FIG. 5. Tangential section. ×180.
FIG. 6. Tangential section. ×180.

PLATE II.

FIG. 7. Transverse section. ×200.

Pityoxylon scituatense.

FIG. 8. Transverse section. ×60.
FIG. 9. Radial section. ×30.
FIG. 10. Tangential section. ×60.
FIG. 11. Tangential section. ×180.
FIG. 12. Tangential section. ×180.

A STUDY OF THE VEGETATION OF THE MESA REGION EAST OF PIKE'S PEAK: THE BOUTELOUA FORMATION.

I. STRUCTURE OF THE FORMATION.

H. L. Shantz.

(WITH MAP AND SEVEN FIGURES)

The region under consideration in this study lies at the base of Pike's Peak and north and west of Colorado Springs. It is the portion known as the Mesa and the Garden of the Gods and contains 3200 to 4000 hectares (*map*). While my attention has been confined largely to this region, studies have been pushed out in all directions, and I have attempted to make myself familiar with the mountain and plains conditions of vegetation, as well as that of the area under consideration. Especial attention was given to the plains which extend eastward from the area first studied.

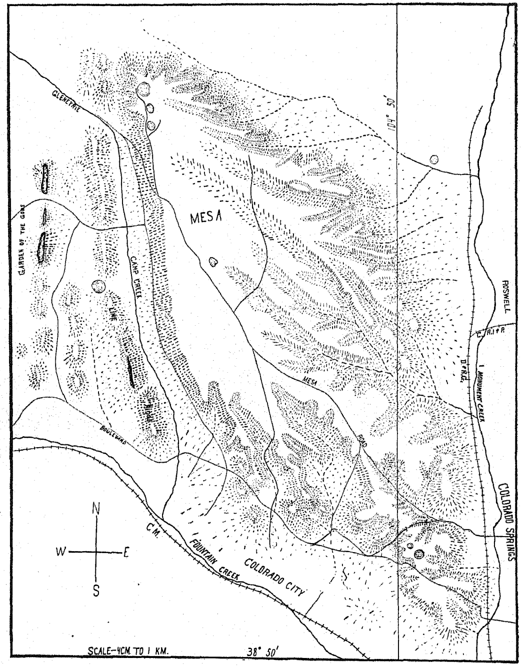
METHODS.

The methods used in the study of the structure and development of the vegetation, as well as in the study of the physical factors, are those used by Clements[1] in his ecological studies and need not be mentioned here. The exact methods have been supplemented by careful field notes and photographs. The greatest care was exercised in physical factor readings. The soil samples for the determination of water content were taken with a soil borer, which gave a column of soil reaching to a depth of 15^{cm} and about 2^{cm} in diameter.

Relative humidity readings were taken as near as possible to the surface, and also one meter above. A constant record of relative humidity was obtained by means of the hygrometer at Colorado City, and the isolated readings were compared with this record as well as with the record of the United States Weather Bureau at Colorado Springs. Temperature readings were taken in the soil

[1] Clements, F. S., Research methods in ecology. Univ. Pub. Co., Lincoln, Neb. 1905.

at a depth of 15^{cm}, at the surface of the soil, on the plant, at 10^{cm} above the soil, and finally 1^{m} above the surface. A constant record was taken by means of a thermograph, and the records of the Weather Bureau were also made use of to check the results thus obtained.



MAP.

In the measurement of light the writer has used the ordinary photometric method, but has used the standard derived from the candle power. Solio paper was exposed to a standard candle for

15 hours at a distance of 10^{cm}. The Hefner-Alteneck lamp burning acetate of amyl was used as a standard. The diameter of the wick was 8^{mm} and the height of the flame was 40^{mm}. The shade produced on the Solio paper was used as a standard and copied in permanent colors. Strips of the same sheet of Solio used to make the standard were exposed and the time required to produce the standard tint recorded. This gave mathematical data and a very simple means of comparing light intensities. The light at the June solstice was about 4.5 seconds. All exposures were made parallel to the soil surface.

In the diagnosis of the habitat I have given the figures found to apply during the time studied. Rainfall, temperature, wind, and humidity are averaged for four seasons. The data in water content are based on a single season's work, but on a great many readings. The data on non-available water were obtained by taking the soil samples at the time when the plants were dying. This water varies not only with the species, but also with the individual plants. The data as collected were largely at the time of the dying of *Boebera papposa*, *Salvia lanceolata*, *Helianthus annuus*, *Verbesina encelioides*, and *Solanum rostratum*, mostly during the latter part of the aestival period; and these results are given in the other diagnoses, since at other times it was impossible under natural conditions to obtain such data. Available water is expressed in grams to 100 grams of dry soil. The duration of each aspect, as well as many of the factors which are definitely stated, varies from year to year.

The species lists are arranged to give an idea of the relative importance of the species under each heading, the most important species appearing first. The lists without the species in parentheses are for the Mesa region only. Important species of the formation which do not occur in the Mesa region are included in parentheses. They will be taken up under the general discussion. In the lists important parasitic fungi always appear after the species upon which they occur.

Within the formation the following are the terms applied to the plant associations: *consocies*, or areas which are dominated by a facies of the formation and which at all periods give the character-

istic stamp to the vegetation; *societies*, or minor divisions, characterized by principal species and dominant usually over smaller areas and only during the aspect in which they occur; *communities*, or smaller associations, usually of secondary species.

GEOLOGY.

The eastern base of the Rocky Mountains shows a great many rock systems which are upturned and all come to the surface in or near this region. Lying on the Archean granite, which forms the mountains at the west, is found a Cambrian red sandstone, gravel or lime. The Silurian or Manitou limestone lies next, followed by the reddish gray quartzite sandstone of the Carboniferous. East of this the Garden of the Gods is formed by the great red sandstone outcrop which is placed in the Permian or in the Triassic—authorities differ. The Jurassic, which lies next, is followed by the Cretaceous rock system, represented by the following epochs. The lowest is of the Dakota—the white sandstone ridge or hogback, and the great sandstone ledges. Lying next and buried in most places under the talus of the latter is the Benton shale. The most eastern of the series of hogbacks marks the outcrop of the Niobrara limestone. The Fort Pierre shale is found in many places east of the lime ridge and underlies the whole Mesa region. Lying above this is found the recent Quaternary deposit of gravel of granitic origin.

The sedimentary deposits underlie the entire Great Plains region, but in most places are covered by the more recent wash from the mountains. For the geological development and structure of the Great Plains, as well as for a description of the topography and climate, the reader is referred to the exceedingly interesting publication by JOHNSON.[2] The following quotation from this source (p. 612) gives a very clear idea of the origin of the plains.

> The Great Plains are of such vast dimensions it is only in imagination that they can be regarded as a foot slope to the Rocky Mountains. However, in the sense that, superficially, ranging down to several hundred feet in depth, they have been built to a smooth surface by mountain waste, stream-spread to great distances, they have this character. At the base of the mountains the Plains mass has a thickness, to sea level, of several thousand feet. It is made up in

[2] JOHNSON, W. D., The high plains and their utilization. Ann. Rept. U. S. Geol. Survey 214: 601–741. 1899–1900.

the main of marine-rock sheets with a general inclination eastward, due to broad regional tilting, in which the plains and mountains have shared together.

But the present surface grade of the Plains is not that of the original tilting. The surface has undergone a series of transformations. These have all been accomplished by the eastward-flowing streams from the mountains. In a first stage the mountain streams, traversing the Plains, cut into the smooth structural slope, and produced a topography of parallel broad valleys and ridges. In a second stage they ceased to cut, depositing instead, and refilling the valleys

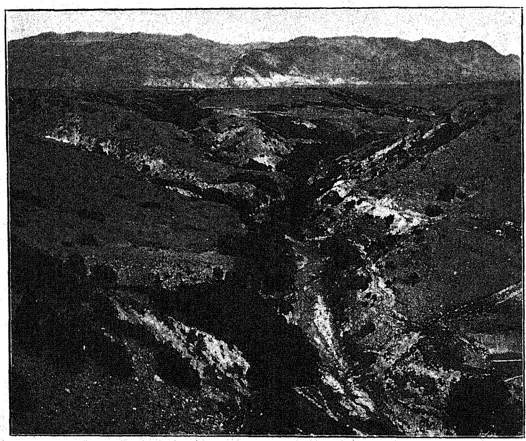


FIG. 1.—Gully on the east side of the Mesa; alternation between thicket and grass formation.

they had excavated, even burying the intervening ridges, to a smooth upper surface. The original surface was a product of deformation, the second of a destructive process of stream erosion, the third a product of stream deposit and construction, involving the spreading of a waste sheet to great distances and a uniform level, and to a depth over the greater valleys often of several hundred feet. In the final and present stage, virtually the same streams have returned to the earlier destructive habit, and erosion has in large part carried away the high level plain of stream construction. About midway of the long slope, in the north-south irregular belt, large uneroded fragments of the smooth constructional plain remain. As we have seen above, these fragments constitute the High Plains.

PHYSIOGRAPHY AND SOILS.

The exposure of the Mesa is southeast, the grade being about 18^{m} to the km. The northwest portion, which is the highest, has an elevation of 1889^{m}. On the east and south sides of this Mesa the water has cut deep gullies (*fig. 1*), which appear older on the south than on the east, the slope being more gradual and the soil more stable. The east side of the Mesa is bounded by a low region largely of clay sand, which slopes gradually to Monument Creek. On the north side there is a less elevated region which, however, does not differ markedly from the Mesa itself. On the west side is Camp Creek, which has cut down into the Fort Pierre clay.

The soil of the Mesa is a gravel mixed with a limited amount of clay and humus. The gullies and edges of the Mesa are made up of Ft. Pierre clay, which is in places mixed to some extent with the Quaternary gravel which lies above it.

CLIMATE.

Rainfall.—The greatest amount of rain is during the growing season, the fall and winter, as a rule, receiving very little. As a result the vegetation is not protected in the least by snow during winter, nor is there a sufficient amount of water to retard the evaporation from the aerial parts of the plant. There is, as a rule, considerable rain during the summer months from May to September, but often the rainy season is much shorter, covering, as it did in 1903, only June, July, and August. The rainfall is about 32 to 43^{cm}, but because of the unequal distribution throughout the year, this affords a rather luxuriant summer growth. This seasonal variation in rainfall is best illustrated by the following table, which gives the rainfall in centimeters.

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1901	0.15	0.17	2.97	4.67	9.52	....	....	5.68	5.58	1.24	0.02	0.45	.....
1902	0.20	0.35	1.01	2.07	13.28	3.96	4.21	6.83	0.40	0.38	0.05	0.55	33.29
1903	0.15	1.77	0.93	2.41	1.57	12.95	1.07	6.29	1.52	0.86	2.03	0.63	32.18
1904	0.27	0.48	0.15	0.58	10.46	9.86	7.87	6.35	5.25	0.67	Trace	1.14	43.08

There is also a daily variation in rainfall which is of some importance to the plant. The relative humidity, of course, is much higher during the night than it is during the day, and on this account rain

which falls in the afternoon and leaves the ground wet at night sinks into the soil and does the plant much more good than does that which is followed by a clear sky and rapid evaporation.

A study of the rainfall record shows that much more rain falls during the afternoon than during the forenoon. During the months of May, June, July, and August, 1904, 72 per cent. of the rain fell in the afternoon; while 71 per cent. of the hours during which rain was falling were in the afternoon. The sunshine record (*fig. 6*) also makes this plain.

Relative humidity.—A deposit of dew is extremely rare. The relative humidity therefore seldom reaches 100 per cent. except during showers. During the day it is generally low, often being as low as 1 per cent.; on account of this, rain or snow is soon evaporated. The relative humidity is especially low during winter when there is little rain and when during the day the temperature often rises to 16°–20° C. The following table gives the relative humidity for each month of the year 1904; and *fig. 2* illustrates the daily variation.

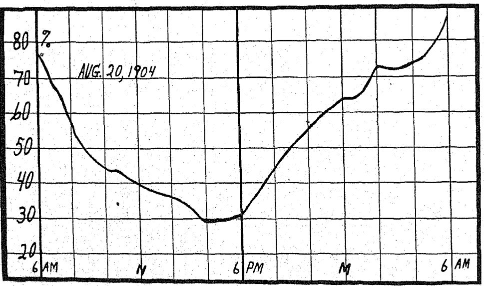


FIG. 2.—Daily variation in relative humidity.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum....	90	89	100	100	100	94	90	95	100	100	89	100
Minimum....	1	8	6	1	11	12	9	21	13	12	12	5
Average......	47	41	42	44	55	54	51	55	44	52	43	49

Wind.—The chief importance of wind is its effect upon the transpiration of the plant and upon the water content of the soil. The

following are the velocities in hm. per hour for the different months of the year 1904: Jan. 4.6; Feb. 3.3; Mar. 5.7; Apr. 6.09; May 4.7; June 3.7; July 3.5; Aug. 3.2; Sept. 3.7; Oct. 3.8; Nov. 4.04; Dec. 4.3.

Temperature.—Extremes in temperature do not occur. The summer temperature is seldom above 32° C., and the winter temperature is seldom −18° C. The maximum temperature recorded during the four years 1901–4 was 36.6 C., and the minimum for the same period −28.3 C. The following temperatures are for the year 1904.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Maximum.	17.7	21.6	20.5	22.8	25.5	28.3	31.6	29.4	28.3	23.3	19.3	18.8
Minimum.	−18.3	−18.3	−14.4	−9.4	−1.1	2.7	6.1	7.2	5.5	−5.5	−5.5	−20.5
Mean.....	− 2.8	2.2	3.9	7.7	11.5	14.9	18.2	19.5	17.3	9.4	5.1	0.2

The mean temperature is derived from the daily maximum and minimum. The daily variation may best be shown by curves from the thermograph (*fig. 3*).

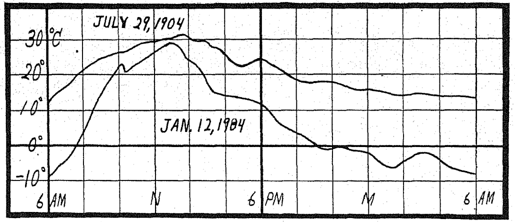


FIG. 3.—Daily variation in temperature.

A comparison of these curves will show clearly how much greater is the daily range in winter than in summer. The curve for January 12, 1901, rises higher than the typical winter curve, but is otherwise normal.

A series of curves showing the variation in temperature between the soil, soil surface, plant surface, 10^{cm} above the soil surface, and 1^{m} above will serve to show how different are the conditions of

temperature under which the plant lives from those ordinarily recorded (*fig. 4*). At the top of the figure is given the sunshine

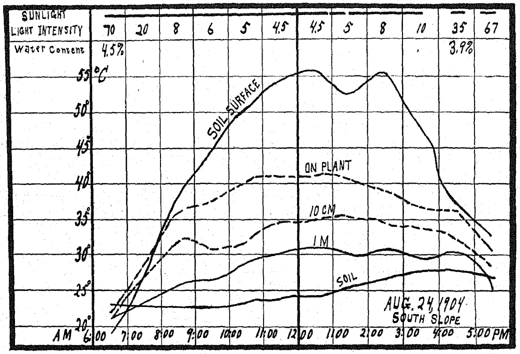


FIG. 4.—Variation in temperature at different levels.

record, together with the light intensity for each hour of the day. The water content was determined twice, as recorded in the figure. The plant surface temperature record was taken on a mat of *Bouteloua oligostachya*, and the quadrat was situated on a south slope.

The extreme conditions at the surface of the soil may account to some extent for the dying of the lower stem leaves, so often noted among perennials as well as annuals.

Simultaneous readings on north, south, east, and west slopes give the curves for soil and soil surface temperatures shown in *fig. 5*. The water content was recorded twice in each quadrat and is also given in the figure; curves of soil temperature are given at the bottom of the figure. Some idea of the temperature at the various levels may be obtained by comparing these curves with those of *fig. 4*. The readings shown by *figs. 4* and *5* are simultaneous.

Light.—The sunshine records taken show 51 to 80 per cent. of possible sunshine. The difference between possible sunshine for the forenoon and afternoon is seven to nine hours per month during

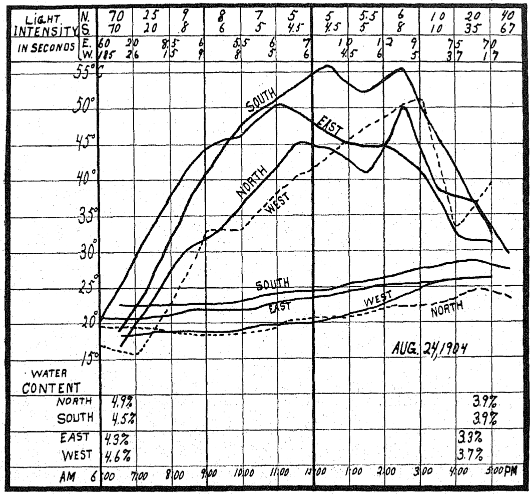


FIG. 5.—Variation in temperature and light intensity on different slopes.

the period of growth. This is due to the mountains which shorten the period of illumination for the afternoon. The rains and cloudy

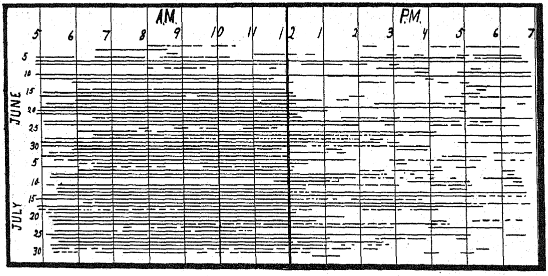


FIG. 6.—Sunshine record.

sky occur most frequently during the afternoon, which on this account also receives much less sun than does the forenoon. The record for sunshine for June and July 1904 makes this clear (*fig. 6*).

The difference in the light received by the east and west slopes, together with the resulting differences in temperature, relative humidity, and water content, is of importance in explaining the vegetation of these exposures.

The Bouteloua (grama grass) formation.

This formation occupies practically the whole Mesa region and the low land surrounding it. It extends for many miles north, south, and east, but no attempt has been made to determine its limits. It seems to be the formation most typical of the high plains and extends eastward far into western Kansas and Nebraska.

The season of growth may be divided into two periods: the vernal, or in this case the spring and early summer period; and the aestival, or late summer and autumn period. Each of these grand periods may be divided into two periods: the first into the prevernal and vernal, the second into the aestival and autumnal.

PREVERNAL ASPECT.

Habitat.—Physical and available water content very low. Rainfall $0.48–2.43^{cm}$ (April 1904, 4.68^{cm}); av. daily, 0.008^{cm}. Relative humidity: mean, 44 per cent.; range 1–100 per cent. Wind 6.09^{hm} per hour. Temperature: mean $7°2$ C.; mean max. $14°4$ C.; mean min. 0° C.; range $-11°1$ to 25° C.; soil, 13° C. Light duration 66 per cent., exposure varied, cover open, soil clay to gravel. Duration April.

PRINCIPAL SPECIES: Leucrocrinum montanum Nutt., Townsendia exscapa (Richards) Porter, Pulsatilla hirsutissima (Pursh) Britton.

SECONDARY SPECIES: Cymopterus acaulis (Pursh) Rydb., Phellopterus montanus Nutt.

The winter conditions are xerophytic, there being very little rain and seldom a snow cover. The mean relative humidity is low—40 to 50 per cent., and sometimes falling as low as 1 per cent. The temperature in winter rarely falls below $-18°$ C. and often rises above 16° C. The records show 56 per cent. of possible sunshine,

and the surface of the soil rises to a temperature much higher than that of the air.

To understand and explain the appearance of the vernal and prevernal flora it is necessary to take into account the winter condition. The water content is low at the time of the appearance of the first flowers. The north slopes have a higher percentage of water than the other exposures, and although the temperature is lower it is here that the greatest number of spring flowers are produced. Only very resistant species seem to be able to survive the long dry winter and produce flowers in the spring on the south slopes. The high temperature which the soil of this exposure reaches during the winter would surely start growth at a period when such development would be disastrous to the life of the plant. This probably explains the abundance of the north slope vernal flora and the paucity of the south slope flora during the same period.

Before the spring rains have begun, at the end of the long dry period, this prevernal flora makes its appearance. These plants are never very abundant on the Mesa proper, but appear in great numbers on the hillsides. In each case the flowers appear either without any foliage or with very little.

The most prominent society of this period is the Pulsatilla society, characterized by P. *hirsutissima.* Its distribution within the region studied is limited to the north slopes and it is never found on the south slopes. The plants are often very numerous and constitute almost the only growing vegetation of this period; forming a zone along the north and east slopes of the Mesa which is only interrupted at places of south or southern exposure.

Leucocrinum montanum forms a society which is less exclusive than the former and is at the same time less distinct. It reaches its maximum development on north crests, but may occur in almost any situation except the south exposure. Over the greater part of the Mesa *L. montanum* is mingled with *Townsendia exscapa,* and these two plants constitute the only vegetation of the Mesa top at this period.

Cymopterus acaulis and *Phellopterus montanus* seldom form communities. In their distribution they show a marked alternation,

C. acaulis occurring on the slopes and crests, usually in the gravelly loam, while *P. montanus* is limited to the clay of the lowland.

The flowers of these species are produced early and are short-lived, most of the foliage being produced after the flowers and continuing during the rainy vernal period, after which the surface parts disappear and the living parts lie buried until the following spring.

VERNAL ASPECT.

Habitat.—Physical water: in clay 13–17 per cent.; in gravelly loam 4.5–9 per cent. Non-available water: in clay 8.5–10 per cent.; in gravel 1.5–2.5 per cent. Available water: in clay 5.6–9.3^{gm} to 100^{gm} of dry soil; in gravel 3.2–7.2^{gm}. Rainfall 12.7–27.9^{cm}; av. daily 0.3^{cm}. Relative humidity: mean 54 per cent.; range 11–100 per cent. Wind 5.33^{hm} per hour. Temperature: mean 14°.4 C.; mean max. 20°.5 C.; mean min. 6°.4 C.; range −2.2 −34°.4 C.; soil 12−25° C.; soil surface to 49° C. Light duration 67 per cent. Exposure varied, cover open, soil clay to gravel. Duration May 1 to July 15.

PRINCIPAL SPECIES: Senecio oblanceolatus Rydb., (Thelesperma intermedium Rydb.), Yucca glauca Nutt., Kellermannia yuccogena Ell. & Ev., Pleospora phragmospora Dur. & Mont., Astragalus Drummondii Dougl., Pentstemon angustifolius Pursh, P. secundiflorus Benth., (Opuntia polyacantha Haw.), (Carex stenophylla Wahl.), (Puccinia caracena DC.), Astragalus bisulcatus (Hook.) Gray, Euphorbia robusta (Engelm.) Small, Uromyces scutellatus (Schrank) Lév., Echinocereus viridiflorus Engelm., Arenaria Fendleri Gray, Sophora sericea Nutt., Uromyces hyalinus Pk., (Oreocarya suffruticosa [Torr.] Greene), (Ipomoea leptophylla Torr.).

SECONDARY SPECIES: Lesquerella montana (Gray) Wats., Tetraneuris glabriuscula Rydb., Aragallus Lambertii (Pursh) Greene, (Astragalus mollissimus Torr.), Astragalus crassicarpus Nutt., Lappula occidentalis (Wats.) Greene, Allium reticulatum Don, Oreocarya thyrsiflora Greene, Euphorbia glyptosperma Engelm., Hymenopappus cinereus Rydb., Thalesia fasciculata (Nutt.) Britton, Mertensia linearis Greene, Pentstemon Jamesii Benth., Eriogonum alatum Torr., Cactus viviparus Nutt., Malvastrum coccineum (Pursh) Gray, Cheiranthus arkansanus (Nutt.) Greene, Anogra coronopifolia (T. & G.) Britton, Gaura coccinea Pursh, Euphorbia serpyllifolia Pers., Tradescantia scopulorum Rose, Thelesperma gracile (Torr.) Gray, Astragalus Shortianus Nutt., Nothocalais cuspidata (Pursh) Greene, Erigeron pumilus Nutt., E. flagellaris Gray, E. glandulosus Porter, E. canus Gray, Carex filifolia Nutt., C. pennsylvanica Lam., Vicia americana Muhl., Aecidium porosum Pk., Quincula

lobata (Torr.) Raf., Leucolene ericoides (Torr.) Greene, Meriolix serrulata (Nutt.) Walp., Lithospermum linearifolium Goldie, Anogra albicaulis (Pursh) Britton, Poa longipeduncula Scribn., Salvia lanceolata Willd., Gaura parviflora Dougl., Hedeoma nana (Torr.) Greene, Antennaria imbricata A. Nels., Evolvulus pilosus Nutt., Thelesperma intermedium Rydb., Sitanion elymoides (Torr.) Greene, Oreocarya suffruticosa (Torr.) Greene.

The vernal period, with which the prevernal is sometimes more or less blended, is ushered in by the spring rains and usually extends from about the first of May to the middle of July. The water content is higher at this period than any other, as is also the relative humidity. Extreme temperatures are not recorded, and the conditions for growth are more favorable than at any other time during the year.

This aspect is marked by the appearance of a great number of seedlings and by many showy flowering plants. The floral display is almost entirely of perennial plants. The earliest species generally appear on the north slopes or north crests, a position protected from the high temperature and excessive loss of water during the winter period.

Societies.

Senecio oblanceolatus society.—This society is by far the most important of the vernal period. It reaches its maximum development in the large gullies on the south side of the Mesa, but the species is distributed over practically the whole area.

Yucca glauca society (*fig.* 7).—This species is one of the most conspicuous plants of the Mesa region and in many places becomes dominant for this aspect. Since the plant is perennial, it is at all times one of the most characteristic of this part of the formation. Species of secondary importance in this society are *Senecio oblanceolatus*, *Euphorbia robusta*, *Lesquerella montana*, *Echinocereus viridiflorus*, and *Mertensia linearis*. This society is found on the gravelly soil, often on crests and slopes where the water content is especially low.

Pentstemon angustifolius society.—On crests in the south part of the Mesa this society reaches its best development. Here the species dominates areas of many square meters, almost to the exclusion of any other species. The chief secondary species of this society are *Lesquerella montana* and *Echinocereus viridiflorus*.

Euphorbia robusta society.—This society occurs on most of the hilltops and over rather large areas of the north Mesa. *E. robusta* is less dominant than the controlling species of the societies already mentioned. *Echinocereus viridiflorus* is in point of numbers more abundant but it is comparatively a very inconspicuous plant. *Senecio oblanceolatus* is not dominant in this society, but ranks second in importance to *Euphorbia robusta;* the society very naturally

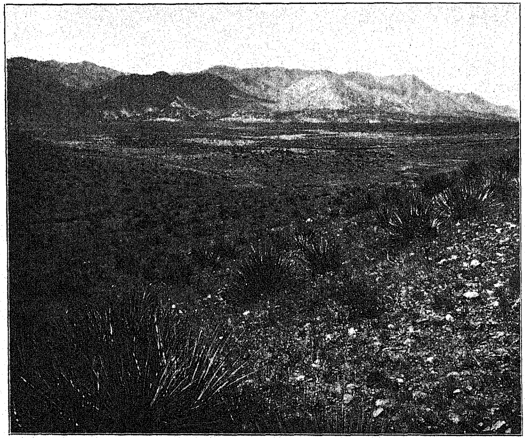


FIG. 7.—Typical Mesa: Bouteloua formation; *Yucca glauca* society.

grading into the *Senecio oblanceolatus* society almost imperceptibly. Secondary species are *Lesquerella montana, Yucca glauca, Oreocarya thyrsiflora, Aragallus Lambertii, Mertensia linearis,* and *Erigeron pumilus.* The soil is a coarse, gravelly loam; water content 6–9 per cent.

Arenaria Fendleri society.—On crests in coarse gravel or gravelly loam, where the water content is low, this society is found. *A. Fendleri* is dominant, but many other species help to make up

the society. Among the more prominent secondary species are *Tetraneuris glabriuscula, Oreocarya thyrsiflora, Hymenopappus cinereus, Meriolix serrulata, Pentstemon angustifolius, Tradescantia scopulorum,* and *Lithospermum linearis.*

Pentstemon secundiflorus society.—No species of this aspect is more dominant than is *P. secundiflorus.* On the crests of the east and north sides of the Mesa it forms an extensive society. *Lesquerella montana, Echinocereus viridiflorus,* and *Evolvulus pilosus* are secondary species.

Astragalus bisulcatus society.—In the clay on the south, east, and west sides of the Mesa, large clumps of this species are very conspicuous at this time of the year. Its maximum development is at the bottom or near the bottom of the hillsides. It usually occurs alone, but we may also find it associated with *Sophora sericea, Quincula lobata, Lappula occidentalis, Allium reticulatum, Malvastrum coccineum,* and *Euphorbia glyptosperma.*

Astragalus Drummondii society.—This is an especially prominent society on north and west slopes, occupying about the same relative position as the *A. bisulcatus* society, but more extensive.

Sophora sericea society.—Although badly affected with *Uroymces hyalinus,* this species becomes the dominant plant in the clay draws of the south Mesa. The chief secondary species associated with it are *Lappula occidentalis, Allium reticulatum, Malvastrum coccineum,* and *Quincula lobata.*

Communities.

Among the secondary species are found a number which form communities. These are generally of limited extent, but are of species which are widely scattered throughout the formation. The following are the more important communities: *Tetraneuris glabriuscula,* on crests; *Lappula occidentalis,* in semiruderal situations; *Erigeron flageolaris,* at the base of north and west slopes, or on the north and west sides of clumps of oak which have entered from the foothill thicket formation; *E. glandulosus,* on north crests; *Carex filifolia,* on portions of the north Mesa and west slopes; *Quincula lobata,* in clay; *Opuntia polyacantha,* either in clay, or on the gravel crests; *Leucolene ericoides,* on south crests and slopes and other

xerophytic situations; *Pentstemon Jamesii*, on clay knolls in the gullies of the south Mesa; *Malvastrum coccineum*, in semiruderal situations; *Gaura coccinea* and *Thelesperma gracile*, on open coarse gravel of north Mesa; *Poa longipeduncula*, on north slopes; *Salvia lanceolata*, in semiruderal situations; and *Antennaria imbricata*, on northwest and rarely northeast slopes.

Most of these communities are closed and contain very few if any other species belonging to this aspect. Any of the species which form societies will also be found to form communities; in fact some of the societies are merely associations of communities.

General.

The chief societies of the Mesa top are the *Yucca glauca* (*fig. 6*) and the *Senecio oblanceolatus* societies. These become more or less mixed in places on the north Mesa. In many places there is formed a mixed society which varies greatly and can only be regarded as a society made up by mixing the other societies and by the addition of widely distributed secondary species. The Mesa top contains besides the two prominent societies mentioned above, a society marked by *Euphorbia robusta*. These three societies alternate, the last named occurring on the north part, the more open part of the formation, in gravelly loam, where the water content is from 6–10 per cent. The *Yucca glauca* society occupies a somewhat more humid region—the crests and Mesa top, especially where the soil is a rocky, gravelly loam, with water content from 7–12 per cent. The *Senecio oblanceolatus* society reaches its maximum development in the gullies, where the loam has a water content of 10–15 per cent.

In addition to these well-marked societies, the following plants occur in varying numbers over practically the whole Mesa top: *Lesquerella montana*, *Pentstemon angustifolius*, *Aragallus Lambertii*, *Astragalus crassicarpus*, *Oreocarya thyrsiflora*, *Erigeron pumilus*, *E. canus*, *Astragalus Shortianus*, and *Mertensia linearis*. Any or all of these species may occur in the societies noted above.

The gravel crests with a water content of from 4.5–9 per cent. are the most xerophytic situations in the formation; and here are found several societies that alternate. Most of the crests of the north and east sides of the Mesa are occupied by the *Pentstemon*

secundiflorus society; the crests of the south Mesa by the *P. angustifolius* society; and the west crests in either situation or on the west side by the *Arenaria Fendleri* society. The alternation between the first two societies is very marked and may be explained partly by the facts of development. *P. secundiflorus* occurs on soil that is less disintegrated, on coarse gravel, or coarse gravelly loam. *P. angustifolius* occurs in older gravelly loam, where the water content is from 2–4 per cent higher; it seems to be more at home on the plains, while *P. secundiflorus* thrives best in the foothill region. These societies also alternate with the *Arenaria Fendleri* society.

There are in this aspect no well-developed societies on the hillsides. The flora of the slopes however, is rather rich and varied. Practically all of the societies are represented here and one may also find many of the secondary species. Crest forms are especially abundant on the south and east slopes.

The alternation between the *Astragalus bisulcatus* society and the *A. Drummondii* society is partly due to the difference in soil. *A. bisulcatus* occurs in clay and is best developed on south and west exposures, usually at the base of the hills. North and west exposures are the most suitable for *A. Drummondii*, which likewise occurs at the base of the hills.

On the lower land surrounding the Mesa the flora is largely of the *Astragalus bisulcatus* society and of the *Sophora sericea* society, together with the following communities: *Lappula occidentalis*, *Quincula lobata*, *Opuntia polyacantha*, *Malvastrum coccineum*, and *Salvia lanceolata*. This vegetation is in the Ft. Pierre clay, a heavy soil with a water content of 13–17 per cent., 8–10 per cent. of which is not available.

As seen by this arrangement, there is zonation exhibited by these societies. This, however, is not very well marked, and the alternation within the zones is much more distinct than the zones themselves.

The reason for this alternation within the formation is to be found in the physical nature of the soil. The soil of the Mesa is a gravel, mixed with a limited amount of humus and silt, or even clay, and is derived entirely from partly decomposed granite and plant remains. The soil is pervious and there is consequently very little run-off,

except during very heavy rains. The total water content varies with the soil composition from 5–14 per cent., and all but 2–4 per cent. is available to the plant. The crests are of a much looser soil, almost pure gravel in places, but generally mixed with clay and silt. The water content here is from 3–4 per cent. lower than on the Mesa top and the formation is much more open. The clay is closely packed and a large percentage of water which falls runs off. The water content is usually less than 17 per cent. and is often as low as 13 per cent., while the non-available water seems to vary with the plant and the slight differences in the amount of foreign substances in the clay from 8.5–10 per cent. After a rain the soil is easily baked to form a hard crust, and when the soil becomes dry, especially during winter, it cracks open to a considerable depth.

The preference which certain plants show for north and west slopes is easily explained by a glance at the sunshine record for June and July. The morning sun heats the east slopes, and as it rises higher the south slope is strongly heated. This hastens transpiration and water loss. The afternoon is cloudy and very likely rainy. The west slope is consequently not strongly illuminated, the soil temperature is from 2–5° C. lower than on the east and south slopes, and the water content is from 1.5–5 per cent. higher. It is the least xerophytic of any situation in the formation.

AESTIVAL ASPECT.

Habitat.—Physical water: in clay 10–13 per cent.; in gravel 2.5–4.5 per cent. Non-available water: in clay 8.5–10 per cent.; in gravel 1.5–2.5 per cent. Available water: in clay 2.3–3.8^{gm} to 100^{gm} of dry soil; in gravel 1–2.1^{gm} to 100^{gm}. Rainfall 7.59–10^{cm}; av. daily 0.137^{cm}. Relative humidity: mean 51 per cent.; range 9–100 per cent. Wind 4.354^{hm} per hour. Temperature: mean 18.8° C.; mean max. 25° C.; mean min. 10.5° C.; range 2.7°–36.6° C.; soil 18–29° C.; soil surface to 55° C. Light duration 55 per cent. Exposure varied, cover open, soil clay to gravel. Duration July 15 to September 15.

FACIES: Bouteloua oligostachya (Nutt.) Torr., B. hirsuta Lag., (Andropogon scoparius Mich.), (A. furcatus Muhl.), (Calamovilfa longifolia [Hook.] Hack.),

Muhlenbergia gracillima Torr., Agropyrum occidentale Scrib., (Koeleria cristata [L.] Pers.).

PRINCIPAL SPECIES: Artemisia frigida Willd., (Thelesperma intermedium Rydb.), (Schedonnardus paniculatus [Nutt.] Trel.), Gutierrezia Sarothrae (Pursh) Britt. & Rusby, (Grindelia squarrosa [Pursh] Dunal), Chrysopsis villosa (Pursh) Nutt., (Eriogonum annuum Nutt.), (Artemisia canadensis Michx.), Lupinus argenteus Pursh), (Carduus plattensis Rydb.), Aristida longiseta Steud., Psoralea tenuiflora Pursh., Aecidium psoralea Pk., Boebera papposa (Vent.) Rydb., Plantago Purshii R. & S., (Selaginella densa Rydb.), (Eriogonum effusum Nutt.), (Sporobolus cryptandrus [Torr.] Gray), (Eriogonum annuum Nutt.)

SECONDARY SPECIES: Oreocarya thyrsiflora Greene, Petalostemon oligophyllus (Torr.) Rydb., P. purpureus (Vent.) Rydb., Euphorbia glyptosperma Engelm., Thelesperma gracile (Torr.) Gray, Gaura coccinea Pursh, Tetraneuris glabriuscula Rydb., Malvastrum coccineum (Pursh) Gray, Atheropogon curtipendulus (Michx.) Fourn., Sideranthus spinulosus (Nutt.) Sweet, Laciniaria punctata (Hook.) Kuntze, Eriogonum Jamesii Benth., Munroa squarrosa (Nutt.) Torr., Euphorbia serpyllifolia Pers., Chenopodium leptophyllum (Moq.) Nutt., Mentzelia nuda (Pursh) Torr. & Gray, Argemone intermedia Sweet, Physalis comata Rydb., Atriplex argentea Nutt., Potentilla pennsylvanica L., Asclepias pumila (Gray) Vail, Bouteloua prostrata Lag., Helianthus pumilus Nutt., Sitanion elymoides Raf., Muhlenbergia gracilis Trin., Artemisia gnaphalodes Nutt., Stipa comata Trin. & Rupr., Stipa Vaseyi Scrib., Allionia linearis Pursh, Artemisia canadensis Michx., Leucolene ericoides (Torr.) Greene, Picradeniopsis oppositifolia (Nutt.) Rydb., Hedeoma nana (Torr.) Greene, Stipa neo-mexicana (Thurb.) Scrib., Chenopodium oblongifolium Wats., Anogra coronopifolia (T. & G.) Britton, Leptilon canadense (L.) Britton, Helianthus annuus L., Andropogon furcatus Muhl., Solanum rostratum Dunal, Ptiloria ramosa Rydb., Chenopodium album L., Helianthus petiolaris Nutt., Quincula lobata (Torr.) Raf., Grindelia squarrosa nuda (Wood) Gray, Carduus undulatus Nutt., Carduus plattensis Rydb., Gaura parviflora Dougl., Potentilla coloradensis Rydb., Eriogonum alatum Torr., Euphorbia stictospora Engelm., Mentzelia decapetala (Pursh) Urban & Gilg, Andropogon scoparius Michx.

An increase in temperature, a decrease in rainfall and relative humidity, together with the resulting decrease in water content of the soil mark the appearance of the aestival period. The percentage of water in the soil is for this period 10–13 per cent. for clay and 2.5–4.5 per cent. for gravel.

This aspect is characterized by the flowering of most of the annual species and by the predominance of the grasses and composites. The facies of the formation are the dominant species of this aspect

and in consequence the principal species are less conspicuous than during the vernal period.

Consocies.

Consocies or areas dominated by the facies of the formation will be discussed later, and need only be mentioned here.

Bouteloua oligostachya consocies.—This consocies is almost as extensive as is the formation, for this species is by far the most abundant of any found in the region studied. A discussion of the consocies is practically a discussion of the typical grama grass formation and will be taken up later. The highest development of this consocies is on the Mesa top, where the water content of this period in the gravelly loam is 4–8 per cent.

Bouteloua hirsuta consocies.—This consocies occupies a more xerophytic habitat, where the water content is 2.5–4.5 per cent. It occurs on the crests and on the north portion of the Mesa in the gravelly soil. With this plant are generally associated *Artemisia frigida*, *Atheropogon curtipendulus*, *Aristida longiseta*, *Bouteloua oligostachya*, *Gutierrezia Sarothrae*, and many crest species. Conditions here are the most xerophytic of any situation in the habitat.

Muhlenbergia gracillima consocies.—This consocies is characteristic of the clay flats where it reaches its best development. It is not uncommon to find places which are dominated by this species almost to the exclusion of everything else. As a rule, however, one finds here *Bouteloua oligostachya*, *Schedonnardus paniculatus*, *Artemisia frigida*, *Gutierrezia Sarothrae*, *Munroa squarrosa*, *Boebera papposa*, *Plantago Purshii*, *Picradeniopsis oppositifolia*, *Euphorbia glyptosperma*, *Argemone intermedia*, *Atriplex argentea*, *Agropyron occidentale*, *Malvastrum coccineum*, and many other secondary species. The habitat is xerophytic, in clay or loam where the water content varies with the soil composition from 17–13 per cent.; the available water being from 2–3.5^{gm} per 100^{gm} of dry soil.

Agropyron occidentale consocies.—This is not so important in the Mesa region as it is farther east. It occurs, however, in the clay, and here is usually associated with *Muhlenbergia gracillima*, *Bouteloua oligostachya*, *B. prostrata*, and *Atriplex argentea*.

Societies.

Artemisia frigida society.—This is by far the most important society of the region. It occurs at the heads of the gullies and on the more depressed places of the north Mesa. It is also important on alluvial fans and areas where there has been a secondary succession. Where this species is abundant, as a rule it shuts out all other plants with the exception of the taller species, such as *Argemone intermedia* and *Stipa Vaseyi.* This society can be distinguished for miles because of the silvery appearance of the plant, which is so widely distributed over the entire Mesa that it would be considered a facies of the formation if it were not for the fact that more extended study shows it to be local in its distribution.

Gutierrezia Sarothrae society.—This composite is rather evenly distributed over the Mesa region, but it can never be said to replace the grasses which are characteristic of the formation. It does dominate rather large areas, however, particularly in the southern part of the Mesa, where it is found associated with many of the characteristic plants of the Mesa top. It does not occur so commonly in the purer gravel soil as in the clay and gravelly loam.

Chrysopsis villosa society.—This society is of considerable importance on the north portion of the Mesa, where it occurs in the *Bouteloua hirsuta* consocies.

The *Aristida longiseta* society is not extensive, but dominates south and east crests and slopes. The *Psoralea tenuiflora* society is extensive, reaching its best development on the hillsides.

The rainy vernal period favors the development of a number of annuals which come into bloom at this time. The most important of these is *Boebera papposa,* which has a very even distribution throughout the region studied. It occurs as a ruderal plant, usually from 4–10^{cm} high and bearing very often only one head. In point of numbers it probably exceeds all but the facies of the formation. However, it succeeds best as a ruderal, and in the formation the small plants may be as numerous as 996 per quadrat and still not be especially noticeable. Wherever there are open spaces in the formation, this society is found.

Plantago Purshii also occurs as an important annual in the forma-

tion. It is also successful as a ruderal, but at places within the formation may become far more numerous than any other species.

Communities.

The following communities also occur: *Schedonnardus paniculatus*, near the mountain and in clay; *Atheropogon curtipendulus*, on north slopes; *Sideranthus spinulosus*, on south slopes and crests; *Atriplex argentea*, in ruderal clay; *Bouteloua prostrata*, in clay south of the Mesa, also in ruderal or semiruderal habitats; *Sitanion elymoides*, on south slopes; *Muhlenbergia gracilis*, on north slopes; *Artemisia canadensis*, on north and west slopes; *Leucolene ericoides*, crests and xerophytic places; *Andropogon furcatus*, on north Mesa in gravel; *Andropogon scoparius*, on gravel crests; *Thelesperma gracile* and *Gaura coccinea* continue from the previous aspect.

Within this area there is one family of *Oonopsis foliosa* (Gray) Greene, which is about three years old and has spread to occupy 25^{sqm}.

General.

In considering the aestival aspect as a whole, much is found that will be discussed under the formation. Zonation during this aspect is shown as in the preceding aspect. The Mesa top is dominated by the typical formation—*Bouteloua oligostachya* consocies—the crests by the *B. hirsuta* consocies, the hillsides by the typical formation tending towards the *B. hirsuta* consocies, and the low lands surrounding either by the typical formation or by this alternating with the *Muhlenbergia gracillima* or *Andropogon occidentale* consocies.

This zonation is largely due to differences in water content. The Mesa top and the slopes have nearly the same water content, there being about $2–3^{gm}$ of available water; the crests have a less amount, $1–2^{gm}$; while at the base, in the clay, the available water is from $2.3–3.8^{gm}$.

The greater part of the Mesa top is occupied by the *Bouteloua oligostachya* consocies. Almost any of the other species noted under this aspect, whether they are primary or secondary, may be found associated with *B. oligostachya*. The most noticeable forms found on the Mesa at this time are *B. oligostachya*, *Muhlenbergia*

gracillima, *Bouteloua hirsuta*, *Artemisia frigida*, *Gutierrezia Sarothrae*, *Boebera papposa*, *Oreocarya thyrsiflora*, *Chrysopsis villosa*, *Schedonnardus paniculatus*, *Petalostemon oligophyllus*, *P. purpureus*, *Psoralea tenuiflora*, *Thelesperma gracile*, *Gaura coccinea*, *Euphorbia glyptosperma*, *Atheropogon curtipendulus*, *Sideranthus spinulosus*, *Lacinaria punctata*, *Eriogonum Jamesii*, *E. effusum*, *Asclepias pumila*, *Helianthus pumilus*, *Sitanion elymoides*, *Artemisia gnaphalodes*, *Castilleia integra*, *Erigonum alatum*, *Pentstemon unilateralis*, *Stipa Vaseyi*, and *Euphorbia stictospora*.

Besides the typical formation, the north Mesa is occupied by the *Bouteloua hirsuta* consocies. In this consocies the following groups occur: the *Chrysopsis villosa* society occupying rather limited areas, low crests, and south slopes; and the following communities: *Sideranthus spinulosus*, *Artemisia gnaphalodes*, *Andropogon furcatus*, and *A. scoparius*.

The crests are the most xerophytic and are occupied by the *Bouteloua hirsuta* consocies. This may alternate, however, with the *B. oligostachya* consocies. Occurring within the former consocies are often found the *Gutierrezia Sarothae*, *Chrysopsis villosa*, and the *Aristida longiseta* societies, as well as the following communities: *Sitanion elymoides*, *Muhlenbergia gracilis*, *Artemisia gnaphalodes*, *Andropogon scoparius*, and *Tetraneuris glabriuscula*. The following plants are also abundant on these crests: *Oreocarya thyrsiflora*, *Chenopodium leptophyllum*, *Stipa comata*, and *S. neo-mexicana*.

The hillsides and slopes have usually about the same vegetation as the Mesa top, but the crest forms may be more abundant.

Passing to the lowlands, the *Bouteloua oligostachya* consocies is found alternating with the *Muhlenbergia gracillima* consocies and also the *Andropogon occidentale* consocies. The chief societies of the *Bouteloua oligostachya* consocies are the *Gutierrezia Sarothrae* and *Artemisia frigida* societies. In the Muhlenbergia consocies are found the *Bouteloua prostrata* and *Atriplex argentea* communities.

Marked alternations sometimes occur between secondary species. *Petalostemon oligophyllus* occurs on south and east slopes, and *P. purpureus* on north and west slopes, where the water content is from 1–2 per cent. higher; *Muhlenbergia gracile*, *Koeleria cristata*, and *Potentilla pennsylvanica* are usually found on north slopes;

while *Aristida longiseta*, *Sitanion elymoides*, *Stipa comata*, *S. neomexicana*, *Physalis comata*, and *Ptilora ramosa* are found on south slopes and crests.

AUTUMNAL ASPECT.

Habitat.—Physical water: in clay 8.5–10 per cent.; in gravel 1.5–2.5 per cent. Non-available water: in clay 8.5–10 per cent.; in gravel 1.5–2.5 per cent. Available water: none in surface soil. Rainfall 1.62–4.03^{cm}; av. daily .006^{cm}. Relative humidity: mean 49 per cent.; range 12–100 per cent. Wind 4.66^{hm} per hour. Temperature: mean 11.6°C.; mean max. 18.8°C.; mean min. 2.7°C.; range $-5.5°-27.2$°C.; soil 18–25°C.; soil surface to 40°C. Light duration 60 per cent. Exposure varied, cover open, soil clay to gravel. Duration September 15 to November 1.

PRINCIPAL SPECIES: Artemisia frigida Willd., Gutierrezia Sarothrae (Pursh) Britt. & Rusby, (Grindelia squarrosa [Pursh] Dunal), Senecio spartioides Torr. & Gray, Chrysopsis villosa (Pursh) Nutt., Chrysothamnus graveolens (Nutt.) Greene.

SECONDARY SPECIES: Lacinaria punctata (Hook.) Kuntze, Oreocarya thyrsifloria Greene, Eriogonum Jamesii Benth., Aster polycephalus Rydb., Machaeranthera cichoriacea Greene, Tetraneuris glabriuscula Rydb., Munroa squarrosa (Nutt.) Torr., Petalostemon purpureus (Vent.) Rydb., P. oligophyllus (Torr.) Rydb., Artemisia canadensis Michx., A. gnaphalodes Nutt., Grindelia squarrosa (Pursh) Dunal, Leptilon canadense (L.) Britton, Machaeranthera viscosa Nutt., Chrysothamnus plattensis Greene, Grindelia squarrosa nuda (Wood) Gray, Eurotia lanata (Pursh) Moq.

During the month of August the rainfall decreases markedly, and is only slight during September. The temperature at this time is as high as at any time during the year, and the result is the rapid loss of water by the soil. Although there is still 8–10 per cent. of water in clay and 1.5–2.5 per cent. in gravel, it is doubtful if there is any available water in the surface soil.

Although many plants continue to bloom, vegetative growth is practically stopped for all annuals and greatly decreased for perennials. There must still be some available water, but all the annual plants which would ordinarily continue to grow and bloom if supplied with only a limited amount of water, have dried up at the

beginning of this period. The grasses are dried, and although they are still a prominent part of the vegetation, they are not a living part. It is an exceedingly xerophytic time, and the plants which are found in this aspect appear throughout the vernal and aestival periods and are now only blooming and ripening their seeds.

Artemisia frigida and *Muhlenbergia gracillima* continue to occupy a most important place. *Senecio spartioides* forms in places an extensive society; while the *Gutierrezia Sarothrae* society is even more noticeable than during the aestival period. *Chrysothamnus graveolens*, a large shrubby composite, forms a small society within this region, but farther east occupies larger areas; it is one of the most showy plants of this aspect. *Aster polycephalus* and *Machaeranthera cichoriacea* form rather extensive communities in the more open parts of the formation. *Chrysopsis villosa*, *Lacinaria punctata*, *Oreocarya thyrsiflora*, *Eriogonum Jamesii*, *Tetraneuris glabriuscula*, *Petalostemon oligophyllus*, *P. purpureus*, *Aristida longiseta*, *Grindelia squarrosa*, *G. squarrosa nuda*, *Artemisia canadensis*, and *A. gnaphalodes* have continued from the preceding period.

The end of this period is not well marked. The plants are dry and resistant, and although frost kills the plants which have a more liberal supply of water, some of these species may continue to bloom as late as December 10. During this late period *Senecio oblanceolatus*, *Argemone intermedia*, *Lesquerella montana*, and a number of other species form rosettes which continue throughout the winter.

Structure of the formation as illustrated by typical quadrats.

Passing now from the aspects to the formation as a whole, the structure may be illustrated best by a number of permanent quadrats. Those species which form mats cannot be well represented in numbers per square meter, and on this account the percentage of surface covered is given instead. The numbers which are also given for these species indicate single plants or seedlings. An estimate is also given of the total amount of surface covered by plant growth.

The following quadrat is typical of the *Bouteloua oligostachya* consocies—the most typical portion of the Bouteloua formation.

Bouteloua oligostachya	134	22%	Senecio spartioides	4
Muhlenbergia gracillima	5	7%	Sideranthus spinulosus	12
Artemisia frigida	6	5%	Boebera papposa	81
Senecio oblanceolatus	9		Plantago Purshii	2
Aristida longiseta	1		Polygonum aviculare	1
Astragalus Shortianus	1		Townsendia exscapa	1
Schedonnardus paniculatus	1		Bryum argenteum	
Chrysopsis villosa	1		Total surface covered	42%

Water content: vernal period 8–13%; aestival 6–8%; autumnal 5–6%. Soil, gravelly loam.

The most important difference in the habitat is in water content, the other factors being practically the same as given under the aspects of the formation.

The following quadrats are also typical of the *Bouteloua oligostachya* consocies, but represent this consocies as modified by the occurrence within it of societies.

Bouteloua oligostachya	47%	Euphorbia stictospora	9
Artemisia frigida	4.5%	Boebera papposa	996
Anogra coronopifolia	21	Anogra albicaulis	2
Senecio oblanceolatus	1	Total surface covered	56%

Water content: vernal period 6–12%; aestival .46%; autumnal 3–4%. Soil, fine gravelly loam.

A quadrat within a *Gutierrezia Sarothrae* society:

Bouteloua oligostachya	168	Eriogonum effusum	5
Gutierrezia Sarothrae	22	Boebera papposa	5
Artemisia frigida	10	Malvastrum coccineum	6
Sideranthus spinulosus	18		

Water content: vernal period 7–15%; aestival 4–7%; autumnal 2–4%. Soil, coarse gravelly loam mixed with lime.

The following quadrat will serve to illustrate a portion intermediate between the *Bouteloua oligostachya* consocies and the *Muhlenbergia gracillima* consocies.

Muhlenbergia gracillima	20	33%	Boebera papposa	36
Bouteloua oligostachya	24	12%	Atheropogon curtipendulus	1
Sideranthus spinulosus	3		Allionia linearis	1
Malvastrum coccineum	5		Echinocereus viridiflorus	1
Artemisia frigida	2		Total surface covered	47%

Water content: vernal period 8–14%; aestival 6–8%; autumnal 5–6%. Soil, loam.

Muhlenbergia gracillima consocies.—This consocies covers the greater part of the lower land, particularly that south of the Mesa. The following quadrat is typical.

Muhlenbergia gracillima		46%	Boebera papposa	25
Schedonnardus paniculatus		6%	Plantago Purshii	9
Bouteloua oligostachya		1%	Senecio oblanceolatus	1
Artemisia frigida	19	1.5%	Hedeoma nana	1
Munroa squarrosa	1		Salvia lanceolata	1
Gutierrezia Sarothrae	9		Euphorbia glyptosperma	1
Picradeniopsis oppositifolia	3		Total surface covered	56%

Water content: vernal period 9–14%; aestival 7–9%; autumnal 5–7%. Soil, loam.

This consocies should also show *Opuntia polyacantha*, *Stipa Vaseyi*, *Argemone intermedia*, *Senecio spartioides*, *Verbena bracteosa*, *Atriplex argentea*, *Malvastrum coccineum*, *Astragalus crassicarpus*, *A. bisulcatus*, *Sophora sericea*, *Quinculata lobata*, *Agropyron occidentale*, and many others.

In places *Muhlenbergia gracillima* is even more dominant than in the quadrat given above, but as one passes to the higher ground it gives way gradually to *Bouteloua oligostachya*.

Bouteloua hirsuta consocies.—This consocies is best developed on the crests and over the north portion of the Mesa. A quadrat best illustrates the structure.

Bouteloua hirsuta	95	17%	Sideranthus spinulosus	7
Artemisia frigida		4%	Oreocarya thyrsiflora	6
Atheropogon curtipendulus		1.5%	Lacinaria punctata	4
Aristida longiseta	4	1%	Gaura coccinea	3
Andropogon scoparius		.5%	Euphorbia robusta	2
Bouteloua oligostachya		.3%	Senecio spartioides	1
Thelesperma gracile	16		Astragalus Shortianus	1
Echinocereus viridiflorus	8		Pentstemon secundiflorus	1
Senecio oblanceolatus	7		Total surface covered	32%

Water content: vernal period 4.5–9%; aestival 2.5–4.5%; autumnal 1.5–2.5%. Soil, coarse gravelly loam. This quadrat also illustrates the structure of the vernal *Euphorbia robusta* society.

While *Bouteloua hirsuta* is predominant in this consocies, many other species are important. *Muhlenbergia gracillima* is sometimes present; *Aristida longiseta* and *Sitanion elymoides* are sometimes

very important; *Andropogon furcatus*, *Yucca glauca*, *Erigeron pumilus*, and *E. canus* are often present.

The physical conditions of this consocies are not essentially different from those of the typical formation, except that the looser, gravelly soil contains less water. It is the most xerophytic of all the consocies. The following crest quadrat from the south part of the Mesa also illustrates this consocies.

Bouteloua hirsuta	35	10%	Artemisia frigida	2
Bouteloua oligostachya	34	3%	Senecio oblanceolatus	2
Aristida longiseta	8	1.5%	Gaura coccinea	1
Atheropogon curtipendulus	30	.5%	Oreocarya thyrsiflora	1
Gutierrezia Sarothrae	7		Echinocereus viridiflorus	1
Senecio spartioides	3		Lecanora subfusca allophana*	20
Pentstemon angustifolius	3		Total surface covered	23%

* Small crusts—a remnant of the more primitive lichen formation.

Water content: vernal period 6–10%; aestival 4–6%; autumnal 2.5–4%. Soil, very coarse gravelly loam.

Societies of the *Bouteloua hirsuta* consocies: *Pentstemon secundiflorus* society found on crests of the north or east part of the Mesa. The following quadrat is typical:

Pentstemon secundiflorus, (81 in bloom)	141		Evolvulus pilosa	7
Artemisia frigida		7%	Sideranthus spinulosus	6
Bouteloua hirsuta	65		Echinocereus viridiflorus	2
Lesquerella montana (seedlings)	40		Mentzelia nuda	4
Boebera papposa	8		Portulaca oleracea	1
			Total surface covered	24%

Water content: vernal period 4.5–9%; aestival 2.5–4.5%; autumnal 1.5–2.5%. Soil, coarse gravelly loam.

Pentstemon angustifolius society.—While *Pentstemon angustifolius* does not form so dense an association as *P. secundiflorus*, the spikes are much larger, and it is therefore very prominent in certain areas. The following quadrat is typical:

Bouteloua hirsuta	17	20%	Artemisia canadensis	2
Pentstemon angustifolius	14	(5%)	Eriogonum Jamesii	1
Aristida longiseta		1%	Thelesperma gracile	1
Chrysopsis villosa	8		Boebera papposa	4
Allionia linearis	5		Euphorbia stictospora	4
Echinocereus viridiflorus	2		Total surface covered	28%
Gutierrezia Sarothrae	2			

Water content: vernal period, 6–12%; aestival 4–6%; autumnal 2–4%. Soil, coarse gravelly loam.

This society belongs to the vernal aspect and alternates markedly with the above-mentioned society. So distinct is this alternation, that on adjacent crests these societies may occur with no mixing of the dominant species. It occupies the south and west crests of the Mesa. The species is widely distributed over the top of the Mesa, but seldom becomes dominant.

The following quadrat is taken from a community of *Leucolene ericoides:*

Leucolene ericoides	78	Eriogonum Jamesii	1
Bouteloua hirsuta	53	Psoralea tenuiflora	1
Aristida longiseta	13	Allionia linearis	1
Eriogonum effusum	3	Chenopodium leptophyllum	1

The *Agropyron occidentale* consocies is not as well developed in this region as elsewhere, but the following quadrat will show the structure. This quadrat is taken from a community of *Bouteloua prostata.*

Bouteloua prostrata	352	Salvia lanceolata	11
Agropyron occidentale	216	Polygonum aviculare	10
Bouteloua oligostachya	47	Picradeniopsis oppositifolia	9
Boebera papposa	123	Quincula lobata	4
Verbesina encelioides	108	Salsola Tragus	2
Gutierrezia Sarothrae	23		

Water content: vernal period 13–17%; aestival 10–13%; autumnal 8.5–10%. Soil, clay.

General discussion.

While the vegetation of the Mesa is typical of the high plains, it does not show all of the structure that is at once apparent upon the examination of a larger area. On the Great Plains lying east, this formation is everywhere in evidence. By far the most important species is *Bouteloua oligostachya*—the dominant species of the formation. That part of the formation which is most typical is the *B. oligostachya* consocies. This consocies is much more closed and pure on the great level plateau farther east than it is near the mountains. It often covers as much as 60–70 per cent. of the surface, and is associated with very few primary or secondary species. In

the clay flats it often gives way to the *Muhlenbergia gracillima* or *Agropyron occidentale* consocies, and in passing to sandy or gravelly ridges it is often dominated by the *Bouteloua hirsuta, Andropogon scoparius*, or *Koeleria cristata* consocies. Even on the slopes or more level sandy areas it alternates with the *Calamovilfa longifolia* consocies, and at times with the *Andropogon furcatus* consocies. Although these consocies dominate immense areas, they are not to be regarded as constituting distinct formations. *Bouteloua oligostacyha* is prominent everywhere and these are merely modifications of the Bouteloua formation, or in other words, consocies of this formation.

To discuss each aspect of this formation would take too much space, and some idea may be obtained by referring to the lists given earlier in this paper.

There is a rather marked zonation in regions characterized by rolling or uneven ground. The hills and ridges are occupied by *Bouteloua hirsuta*. In this habitat there is a rather marked alternation with other consocies. *Andropogon scoparius* often becomes dominant, as does also *Koeleria cristata*. Here are also found a number of prominent societies, among which the most xerophytic is the *Selaginella densa* society. *Sporobulus cryptandrus* and *Stipa comata* may also become prominent.

Occupying the sides cf the slopes and the level expanses is the extensive *Bouteloua oligostachya* consocies. Alternating with this is found the *Andropogon furcatus* and the *Calamovilfa longifolia* consocies. This alternation is often very marked, the consocies remaining distinct from each other.

It is here that the most important societies of the formation are found, many of which extend for many miles without interruption. Among the most prominent of these societies is the *Grindelia squarrosa* society, which extends for many miles east of Limon, Col., and occurs over less extensive areas in many other parts of the formation. The *Schedonnardus paniculatus* society occurs throughout the formation and in many places is very extensive. Between Burlington, Col., and Goodland, Kans., the society extends for many miles. *Thelesperma intermedium* also occurs in this consocies. It is one of the most prominent societies in the formation and is especially

well developed just east of Colorado Springs. The *Gutierrezia Sarothrae* society occurs more often near the mountains and bluffs. *Artemisia canadensis* is also important in similar locations, while *A. dracunculoides* is most abundant farther out on the plains. *Opuntia polyacantha* in most places merely forms small communities or families, but in many places on the plains these become associated into an extensive society. This is especially true east and south of Fountain, Col. *O. arborescens* is also found in this region and extends northward to within a few miles of Colorado Springs.

Carex stenophylla, Senecio oblanceolatus, Sophora sericea, Astragalus Drummondii, Oreocarya suffruticosa, Eriogonum annuum, Chrysopsis villosa, Boebera papposa, and *Plantago Purshii* each form extensive societies in this consocies. The following societies are not so extensive, but on account of the prominence of the plants characterizing them they are very noticeable: *Ipomoea leptophylla, Yucca glauca, Lupinus argenteus, Carduus plattensis, Eriogonum effusum, Chrysothamnus graveolens, Senecio spartioides, Pentstemon angustifolius, P. secundiflorus,* and *Astragalus bisulcatus.*

Passing now to the lowlands, the *Bouteloua oligostachya* consocies is found with very few primary or secondary species, and usually alternating with the *Muhlenbergia gracillima* and the *Agropyron occidentale* consocies. These consocies are sometimes mixed, but as a rule remain distinct. *Agropyron occidentale,* a tall slender grass, is usually not associated with many other species, and the mats of *Muhlenbergia gracillima* also leave little space for the development of any but a few of the clay-loving annuals. *Astragalus bisulcatus, Sophora sericea, Boebera papposa, Plantago Purshii,* and *Atriplex argentea* are among the most important secondary species of these consocies.

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CONTRIBUTIONS FROM THE ROCKY MOUNTAIN HERBARIUM. VII.

AVEN NELSON.

Cypripedium Knightae, n. sp.—Stem short, 3–7^{cm} high, sparsely and coarsely villous, bearing a single pair of nearly opposite leaves at its summit: leaves oval, generally rounded and obtuse, thickish, 4–7^{cm} long: peduncle glandular-viscid, 3–10^{cm} long, usually naked, rarely with a lanceolate bract near the middle: floral bracts rather large, elliptic-lanceolate: flowers 2 or 3 in a cluster, dark-purple: lower sepals united nearly to the tip, ovate-lanceolate, the two together no broader than the other sepal: petals similar, a little broader than the sepals: lip 10–12^{mm} long, somewhat shorter than the sepals and petals, the deeply infolded free margin deep-purple, the lower part of the sac ochroleucous or greenish-yellow: sterile anther elliptic, obtuse, much shorter and smaller than the large conspicuous stigma.

This species, in so far as it has been collected, has seemingly passed as *C. fasciculatum* Kellogg, Wats. Proc. Am. Acad. 17:380. That is a very different thing, as may be seen by referring to the original description, or to Howells's Fl. N. W. Am. 632. It is, moreover, of a quite different geographical range. I have great pleasure in naming this fine species for Miss Harriet Knight, whose sympathetic interest in all nature and whose intelligent activity in the educational work of Wyoming is greatly appreciated.

Collections at hand: *Miss Knight*, Medicine Bow Mts., Wyo., at Cooper Hill, July 1905 (type); *L. N. Goodding*, no. 1201, Uinta Mts., Utah (Dyer Mine), June 30, 1902; *G. E. Osterhout*, Estes Park, Colo., July 1897; and Encampment Creek, Sept. 1897.

Montia Viae, n. sp.—Annual, with fibrous roots: stems and petioles weak, suberect, 10–15^{cm} high: leaves delicately thin, pale-green; the radical several, slender-petioled, the short blades from linear to oval, acute; the single pair of cauline connate and forming a circular or slightly irregular involucral disk 10–20^{mm} broad: raceme peduncled, with a pair of green bracts at the base of the lower pedicels: flowers very small, several: sepals broadly oval, even in fruit less than 2^{mm} long: petals 5, spatulate, barely equalling the sepals,

very delicate, apparently often wholly wanting: stamens 5, very short: ovule solitary; the seed small, oval, slightly compressed and subcarinate, minutely but distinctly papillose-roughened and with a waxy conspicuous strophiole.

Most nearly related but very distinct from *M. perfoliata* (Donn.) Howell, Erythea 1:38, a plant of the Pacific states. Possibly all of the central Rocky Mountain specimens named *M. perfoliata* belong here. The type specimens were collected by the Misses *Dorothy Reed* and *Vie Willits*, June, 1905. Miss Willits, in whose honor the plant is named, later secured an abundance of fruiting specimens. Type locality, shady muddy banks, Big Horn, Sheridan Co., Wyoming.

Lesquerella latifolia, n. sp.—Perennial, silvered with a fine lepidote stellate pubescence throughout: stems numerous, from among the crowded rosulate crown leaves, decumbent at base, spreading, 5–15^{cm} long: radical leaves suborbicular, oval, or rhombic, sometimes broader than long, from 1–3^{cm} in diameter; the petioles slender, often much longer than the blade; cauline leaves from broadly obovate to spatulate, all cuneately tapering into a slender petiole: racemes of showy bright-yellow flowers dense, elongating in fruit: petals spatulate, 9–10^{mm} long, twice as long as the oblong sepals: siliques elliptic, very perceptibly stipitate, 5–6^{mm} long, erect on S-shaped pedicels of about the same length; style slender, 3–4^{mm} long; cells about 5-ovuled.

This is based upon Mr. L. N. Goodding's no. 625, from Karshaw, Meadow Valley Wash, southern Nevada, Apr. 26, 1902. It has been distributed as *L. montana*, a species from which it is as far removed as to characters as it is geographically.

Lesquerella Lunellii, n. sp.—Pale green, moderately and minutely stellate-pubescent throughout: caudex a mere crown surmounting the slender tap root: stems few to several, ascending or assurgent, very slender (almost filiform), 3–15^{cm} long (including the raceme): leaves narrowly linear-oblanceolate, 1–2^{cm} long; the lower tapering into the slender petioles: raceme at length open and long for the plant: sepals purplish-green, linear-oblong, subacute, 4–5^{mm} long: the spatulate-obovate petals nearly twice as long, the upper half of the blade a fine purple, shading into the yellow of the lower half and the claw: silique globose, 4–5^{mm} in diameter; the slender

style as long and the ascending or often recurved pedicel usually distinctly longer.

Dr. *J. Lunell*, of Leeds, N. D., an enthusiastic student of the northwest flora, communicated the specimens to me. I have pleasure in naming the species in his honor. He writes: "It grows on high barren hills among rocks. Its petals are broadly purple-tipped, and the base a bright-yellow." Collected at Butte, Benson Co., N. D., June 13, 1905.

Lepidium Zionis, n. sp.—Glabrous perennial, 1–2^{dm} high: stems several from the crown of a rather thick semi-fleshy vertical root, decumbent at base but assurgent-erect, each corymbosely branched at summit: all the leaves erect, quite entire, thick or subcoriaceous, acute or apiculate; radical leaves oblong, 2–3^{cm} long, tapering to a slender petiole as long as the blade; cauline leaves very numerous, almost imbricated, linear-lanceolate, 15–25^{mm} long: racemes short, crowded: sepals elliptic, scarious margined, half as long as the obovate-cuneate white rather conspicuous petals: stamens 2: silique ovate or elliptic, somewhat keeled, glabrous, not emarginate; the style and small stigma one-fourth as long.

This quite unusual species rests upon but one collection at present, *M. E. Jones*' no. 5411, Richfield, Utah, June 13, 1894.

Cardamine incana (Gray), n. n.—*C. cordifolia incana* Gray, Jones in Proc. Cal. Acad. Sci. II. **5**:620. 1895; *C. cardiophylla* Rydb. Bull. Torr. Bot. Club **28**:280. 1901; not *C. cardiophylla* Greene, Man. Bot. 19. 1894.

Euphorbia Aliceae, n. sp.—Perennial from slender horizontal rootstocks, glabrous or slightly puberulent, 10–15^{cm} high: stem branching from the base, the branches spreading-decumbent: leaves narrowly oblanceolate, short-petioled, sharply serrate, opposite, more crowded toward the terminal clustered involucres: involucres nearly sessile, small, turbinate, somewhat fimbriate-margined; the glands about 4, small, short-stipitate, sometimes minutely cornuate or even obscurely appendaged: capsule glabrous: seeds subcubical, with a caruncle, slightly tuberculate, ashy.

Known as yet only from Hartville, Wyoming, no. 549, collected July 15. 1894. Named in honor of Mrs. *Celia Alice Nelson*, whose industry as a collector is responsible for thousands of specimens found in the leading herbaria, although her name has never appeared on a plant label.

Delphinium Cockerelli, n. sp.—Tawny-pubescent on stems and in the inflorescence, densely and viscidly so above; the leaves obscurely pubescent: stems nearly simple or bushy-branched, 6–12^{dm} high: leaves large, often 12–18^{cm} in diameter, the veins strikingly superficial, about 5-cleft or parted into broadly oblong or oblong-cuneate divisions, these merely coarsely toothed or incised above the middle: racemes often several, open, with rather long peduncles and pedicels and few flowers (5–10): flowers bright-purple, large (3–4^{cm} long): sepals oblong-lanceolate, acute, about as long as the thick curved spur: petals small; the upper yellowish-white, concealed within the upper sepal; the lower purple, with suborbicular blade, cleft and sparsely hirsute ciliate.

An unusually handsome species, with somewhat the aspect of *A. subalpinum* (Gray) A. Nels. Bull. Torr. Bot. Club **27**:263. The type was collected by Mrs. *O. St. John*, no. 90, Baldy Mts., Elizabethtown, N. M., Oct., 1898. It was communicated to me by Professor Cockerell, who called my attention to some of its distinguishing characters. *C. F. Baker's* no. 325, near Pagosa Peak, Colo., is also quite typical.

Aconitum lutescens, n. sp.—Root small, fusiform-tuberous: stems slender, simple, erect, only 3–6^{dm} high, glabrous nearly to the inflorescence: leaves 3–5^{cm} broad; the 5 broadly cuneate divisions deeply and incisely toothed above the middle: raceme narrow, long for the plant, rather open; the flowers a pure cream-color, becoming nearly white or pinkish in drying; rachis and pedicels softly hirsute-ciliate with straight viscid hairs standing out at right angles.

This Aconitum with its fine cream-colored flowers may best stand as a species. Collections of it are as follows: *Aven Nelson*, no. 1521 (type), Cummins, Wyo., July 1895; *T. D. A. Cockerell*, no. 87, Beulah, N. M., 1898; *W. S. Cooper*, no. 274, Estes Park, Colo., July 1904.

Anemone zephyra, n. sp.—Green but sparsely long-pilose: stems one or more from the thick erect caudex, 7–15^{cm} high, rather stout: basal leaves petioled, ternate, the broad petiolulate segments in turn deeply incised into linear-oblong lobes; involucral leaves sessile, with linear-oblong lobes: flowers large, 2–3^{cm} broad, lemon-yellow or ochroleucous, usually solitary and rather long-pedunculate, sometimes umbellately 2–4-flowered: achenes large, glabrous, obovate, tapering to a stipe-like base, tipped with the short hooked style.

There seems to be no good reason for continuing the name *A. narcissiflora* for this plant of the central Rocky Mountains. That Arctic species is white-flowered, the flowers very closely umbelled in the involucre, and the leaves are cleft into many more lobes than ours. The proposed species probably includes all the specimens from the Rocky Mountains of the United States distributed as *A. narcissiflora* or *A. albomerus* (ined.).

Anemone stylosa, n. sp.—Low from a thickened simple or branched caudex densely covered with the dead sheathing petioles: basal leaves pale green, glabrous, biternate, segments 3-parted, again incised into linear-lanceolate acute lobes; involucral leaves short-petioled, otherwise quite similar: stems and petioles sparsely long-pilose, the hairs spreading or refracted: sepals oval or oblong, purplish red or greenish red: achenes pubescent, with rather long straight glabrous persistent styles hooked at the tip.

This I take it is the plant referred to *A. tetonensis* in Syn. Fl. N. A. **1**:10. As yet reported only from type locality, Fish Lake, Utah, *M. E. Jones*, nos. 5763 and 5764, Aug. 7, 1894.

Clematis plattensis, n. sp.—Stems clustered on the crown of a thick woody root, 12–18^{cm} high, terminated by the single stout peduncle of nearly equal length in fruit, sparsely short-villous: basal leaves small, scale-like and entire: foliage proper of about 3 pairs of nearly simply pinnate short-petioled leaves; pinnae 7–9, the lowest pair sometimes ternate, all distinctly petiolulate (petiolule 3–10^{mm} long) and long-villous: achenes long-tailed, hairy-plumose: flowers not known, presumably much like those of *C. Douglasii.*

Type from the North Platte Cañon, in eastern Wyoming, *Aven Nelson*, no. 8355, July 2, 1901.

RANUNCULUS JOVIS A. Nels. Bull. Torr. Bot. Club **27**:261. 1900.

This it turns out is *R. digitatus* Hook., an untenablê name, as it is antedated by *R. digitatus* Willd. *R. Jovis* will therefore have to stand for Hooker's plant.

Ranunculus platyphyllus (Gray), n. n.—*R. orthorhynchus platyphyllus* Gray, Proc. Am. Acad. **21**:377. 1886; *R. maximus* Greene, Bull. Torr. Bot. Club **14**:118. 1887.

There seems to be no good reason why Dr. Gray's name should have been rejected.

Saxifraga oregonensis (Raf.) n. n.—Diminutive perennials from a slender caudex: stems simple, 3–8^{cm} high, glandular-pubescent: the

leaves small, mostly basal, oblong-spatulate, minutely hispid-ciliate: flowers few, in a crowded glomerule at summit: calyx minutely glandular-pubescent, its whole tube adnate to the carpels: petals broadly obovate-cuneate, truncately rounded at summit, twice as long as the calyx lobes, distinctly divergently 3-nerved: the distended subglobose calyx-tube papillose-rugose from the pressure upon it by the numerous brown seeds within.

This is the rare and troublesome little alpine plant of the middle Rocky Mountains which has been referred to *S. adscendens* L., an arctic plant from which it seems to be distinct. The other names which it has also borne are *S. petraea* L. and *S. controversa* Sternb., both of which seem to refer to *S. adscendens* L., and are furthermore both encumbered by synonyms through their application to other very distinct species. Therefore it seems best to take up Rafinesque's name, under Ponista (*P. oregonensis* Raf. Fl. Tellur. 2:66.1836), as there can be no doubt as to its application to our plants.

SAXIFRAGA SUBAPETALA **normalis**, n. var.—Very similar to the species, but petals evident, elliptic-spatulate, as long as the calyx-lobes: as in the species the carpels are immersed in a crest-margined disk which persists at the middle of the mature carpels as an undulate ridge.

For the description of the species see Erythea 7:169. 1899. This has been distributed by various collectors either as *S. integrifolia* or as *S. Sierrae*, from both of which it is quite distinct.

Parthenocissus laciniata (Planch.), n. comb.—*P. quinquefolia laciniata* Planch. in DC. Mon. Phan. 5:449. 1887; *P. vitacea* (Knerr) A. S. Hitch., Sp. Fl. Man. 26. 1894.

Prunus ignotus, n. sp.—Shrubby or possibly becoming tree-like: branches slender, none of them becoming indurated or thorny: leaves glabrous from the first, simply and sharply serrate: flowers white, appearing with or after the leaves, solitary or 2–3 in a cluster: calyx turbinate; its lobes entire, glabrous within and nearly so without: petals obovate: fruit not known.

It is a little singular that no one has reported this in fruit, but the fine specimens distributed by Prof. *C. S. Crandall*, as *P. pennsylvanica*, from the banks of the Cache la Poudre, near Ft. Collins, Colo., May 1897, cannot well be ignored.

Philadelphus intermedius, n. sp.—A low branching shrub with dark green glabrous aspect: leaves short petiolate or subsessile,

broadly oval to ovate, rounded at base and either subacute or obtuse at apex, entire, glabrous or with some scattering ciliate hairs closely ciliate on the margins with short incurved hairs, 15–25^{mm} long: flowers medium size, a 3-flowered cyme from the terminal pair of leaves, a pair of flowers in the next pair of leaves, and sometimes another pair in the axils of the next lower pair of leaves—thus all the flowers except the terminal one are foliose-bracted: calyx glabrous, its lobes finely pubescent within: petals oval, about 12^{mm} long: stamens 30 or more: styles united for two-thirds of their length, the free portion as long as the abruptly enlarged stigmatic portion.

This is most nearly allied to *P. Lewisii* Pursh, from which its smaller size, smaller leaves, smaller flowers, and peculiar stigmas distinguish it. In *P. Lewisii* the styles are united throughout, the stigmatic portion as long as the style proper, the stigmatic line being broad and capping the summit of the stigma and then extending down to the styles in a narrowing line. *P. intermedius* seems to be a connecting species between the desert species of Utah and Colorado and those larger forms of the humid northwest.

Philadelphus nitidus, n. sp.—Slenderly and divaricately branched: leaves rather few, shining and with glaucous hue on both sides, nearly glabrous above, minutely appressed strigose below, mostly narrowly lance-oblong, subacute at both ends, very short petioled, 1–2^{cm} long: flowers generally solitary at the ends of the branchlets: calyx cleft below the middle, hirsute on the outside, soft pubescent on the inside of the lobes: petals elliptic, entire, 8–10^{mm} long, twice as long as the calyx lobes: stamens 30–40: styles distinct down to the ovary: stigmas short, slightly geniculate at junction with filament.

The following collections of this species are at hand: *H. N. Wheeler*, no. 425 (type), Sapinero, Colo., 1898; *C. F. Baker*, no. 266, Black Cañon, Colo., June 27, 1901; *M. E. Jones*, no. 6303, Belknap, Utah, June 28, 1899.

LARAMIE, WYOMING.

BRIEFER ARTICLES

ANTHOCEROS AND ITS NOSTOC COLONIES.

The association of the liverwort Anthoceros with the blue-green alga, Nostoc, has long been known and has been studied with considerable care. The significance and value of this association have been speculated upon; but, as far as I know, no experiments on the subject have been reported. The anatomical relations of the two associates have been studied and described, but I do not know that cultures of Anthoceros from the spore on sterilized soil have been attempted. I shall here describe both the culture of Anthoceros, and, at the risk of some repetition of facts already recorded by others, the anatomical relations of the Nostoc to the surrounding tissue.

Anthoceros fusiformis Aust., and *A. Pearsoni* M. A. Howe fruit here abundantly in May. Their spores can then be collected almost or quite unmixed and free from the spores of other small plants, and may be kept air-dry for months. The dry season ordinarily lasts from mid-May to October, and during this time usually no rain falls. The spores germinate out of doors soon after the first abundant rain has thoroughy moistened the soil to a depth of several inches. The natural "resting-period" for the spores is, therefore, four or five months long, but the spores retain their vitality much longer. They may also be made to germinate in much shorter time. The "resting-period" seems to be, therefore, a matter of natural conditions rather than of transmitted habit.

The soil on which I grew plants from the spore was brought into the laboratory from the bank on which these plants, along with other small archegoniates, grow abundantly during each rainy season. After thorough air-drying, the soil was freed from pebbles, pulverized in a mortar, and put to a depth of a centimeter or slightly more in crystallizing dishes of thin white glass. These dishes were about 8^{cm} in diameter, 3.5^{cm} in depth, and were covered by the lids or bottoms of Petri dishes. These covers do not fit tightly; at the same time that they exclude dust and maintain the moisture of the air, they permit fair ventilation. The soil was invariably moistened from the beginning with boiled distilled water, for I wished to avoid any accumulations of salts in these undrained cultures from using our hard tap-water. These covered dishes were now divided

into two lots of equal number, one lot being put aside in the dark for a few days and the other steam-sterilized for two or three hours on three successive days. This sterilization proved thorough so far as blue-green algae are concerned, since none developed in the dishes. A certain amount of infection is unavoidable, and a few cultures in each lot had to be thrown away because of the development of some "damping-off" fungus. But on the whole the plants in my cultures have done quite as well as those out of doors. During the growing season now ending they did better than those out of doors, because November and December were cold and dry.

Eleven or twelve weeks after sowing, the small plants already bear archegonia and antheridia when the cultures are kept under suitable conditions of illumination. Cultures kept too dark will contain few if any fruiting plants, though the plants may be normally large. From this fact, though I have not attempted to support this view by further investigation, one may infer that light acts as a stimulus to the development of the reproductive organs as VÖCHTING[1] and KLEBS[2] have shown to be the case in certain flowering plants and fresh-water algae.

On comparing the young plants on sterilized and on unsterilized soil the greater size and more robust appearance of the plants on sterilized soil is evident. The plants on sterilized soil contained no Nostoc colonies. The plants on unsterilized soil contained Nostoc colonies, few of them bore reproductive organs, and they appeared less thrifty. But the young Anthoceros plants on unsterilized soil were obliged to compete not only with each other but with several other sorts also. Without attempting an exhaustive list of these other plants I may record the presence, in the cultures, of prothalli of *Gymnogramme triangularis*, fronds of *Fimbriaria Californica*, two or three small mosses, both protonemal and adult, some green algae (especially a small Vaucheria), some blue-green algae (Nostoc, Oscillatoria, Anabaena), chickweed, and grass. Besides these, which started from spores, seeds, or other resting stages, there were small plants which had held over the dry season as CAMPBELL[3] has described, fern prothalli and plants of Fimbriaria and Anthoceros.

Where young plants of Anthoceros have to compete in small cultures with such a number of individuals and of kinds of already fairly established plants, it is natural to assume that this amount of competition may

[1] VÖCHTING, H., Ueber den Einfluss des Lichtes auf die Gestaltung und Anlage der Blüthen. Jahrb. Wiss. Bot. 25:149. 1893.

[2] KLEBS, G., Die Bedingungen der Fortpflanzung bei einigen Algen und Pilzen. Jena, 1896.

[3] CAMPBELL, D. H., Resistance of drought by liverworts. Torreya 4:81. 1904.

have much to do with their less thrifty appearance. However, the presence of Nostoc colonies on the soil does not necessarily imply the infection of all Anthoceros plants near them. As a matter of fact, a good many Anthoceros plants free from Nostoc can be found on unsterilized soil. These look better than those beside them containing Nostoc colonies, and as well as those in the dishes of sterilized soil.

Where cultures receive light mainly from the side, as is generally the case in a laboratory, Anthoceros plants, like fern-prothalli and the thalli of Fimbriaria, turn up from the surface of the soil, presenting their normally upper surface toward the window and bearing rhizoids on the shaded side. These plants necessarily contain fewer Nostoc colonies than those remaining flat on the soil, for the younger and elevated parts are less accessible to Nostoc filaments. Comparisons of older cultures than those just described shows that Anthoceros plants containing only one or two algal colonies are nearly or quite as thrifty as those with none, and are decidedly more vigorous than those with many.

PRANTL[4] attributed an advantage to Anthoceros from its association with Nostoc, on the ground that Nostoc might fix the free nitrogen of the air and contribute its products to the liverwort, but the weight of evidence seems now to be against the assumption that blue-green algae by and of themselves add at all to the combined nitrogen in the soil,[5] whatever the results of their association with N-fixing soil bacteria may be. The fact that, in my cultures at least, Anthoceros does better when free from Nostoc, removes all ground for PRANTL'S claimed advantage from the association so common in nature.

On the other hand JANCZEWSKI'S designation of the Nostoc colonies as parasitic[6] is not logically justified by my cultures or by the luxuriance in growth and by the fertility of these two species of Anthoceros in this region in ordinarily good seasons. Last year they throve as I never saw them before. This season has been by no means so favorable, dry weather having come long before the plants, held back by the cold and dryness of November and December, could ripen their spores in large numbers. All I feel inclined to say is that Nostoc certainly does not benefit Anthoceros, which in fact does better without it.

It is a matter of common observation that many blue-green algae

[4] PRANTL, K., Die Assimilation freien Stickstoffs und der Parasitismus von Nostoc. Hedwigia **28**:135. 1889.

[5] PFEFFER, W., Pflanzenphysiologie, 2te Auflage, 1:386–7, 393. 1897.

[6] JANCZEWSKI, A. DE, Vergleichende Untersuchungen über die Entwickelungsgeschichte des Archegoniums. Bot. Zeit. 377 ff. 1872.

thrive best where there are considerable quantities of organic matter.[7] It is conceivable that Nostoc profits from intimate association with green plants, but to prove the parasitic nature of such association is very difficult. I could not detect that the Nostoc cells, filaments, and colonies within the thallus of Anthoceros appear healthier, or larger, or grow more rapidly, than those on the moist earth near by. The cells of this and many other blue-green algae are so small and the organs of the cell so slightly differentiated that differences between cells are by no means noticeable. From the evidence at hand it is equally unsafe to say that Nostoc is or is not parasitic in Anthoceros.

Passing now to anatomical considerations, PRANTL[8] asserts that the characteristic development of the thallus cavities and the formation of internal hairs follows the entrance of Nostoc filaments only, not of any other small plants. The manner of infection I will not go into, for it has been repeatedly described.[9] The invading filament, if it survives, gives rise to a colony, spheroidal in form and enclosed in gelatinous matter which increases with the growth of the colony. Mechanical pressure, increasing with the growth of the colony and with the amount of water absorbed, is brought to bear against the surrounding cells of the thallus, enlarging the cavity which the Nostoc filament entered through one of the slime-slits on the surface. Another effect of the increasing pressure is the compacting of the immediately surrounding tissue. But because the Nostoc colony is not homogeneous, being in part cells and in part the gelatinous product of these cells, the pressure is not equal over all parts of the surface. The gelatinous matter between the filaments is softer and more readily penetrated or displaced than the filaments themselves. If small thallus cells lie opposite to and in contact with these gelatinous parts of a colony, they will necessarily be pushed forward by their neighbors. As has long been known, chains of cells, constituting the internal hairs above mentioned, do grow into the colonies and among the filaments of Nostoc. Other organisms, though they may enter the body of the liverwort, either do not exert any pressure at all, being smaller than the cavities they occupy, or form such compact masses that there is no chance for the surrounding cells to grow out as chains.

From this consideration of the structure and mechanics of the Nostoc colony, we are led to see the fallacy of PRANTL's argument that, because

[7] See for example KIRCHNER, O., Schizophyceae in Engler & Prantl's Natürliche Pflanzenfamilien. I. 1^a:48. 1898.

[8] PRANTL, K., *loc. cit.*

[9] CAMPBELL, D. H., Mosses and Ferns, Ed. 2, 128. New York, 1905.

cavities and hairs do not develop in the familiar way except where Nostoc colonies are, the liverwort must profit by such associates. It is simply a matter of mechanics. Where the resistance is less than growth can overcome (and this is the case between the Nostoc filaments in the gelatinous mass), the liverwort cells will grow out, forming short hairs. The growing and swelling colony as a whole will enlarge the cavity in which it lies. There are other intercellular spaces throughout the thallus, but these are not enlarged because not occupied. There is no conceivable advantage in their enlargement.—GEORGE J. PEIRCE, *Stanford University, California.*

DISTRIBUTION AND HABITS OF SOME COMMON OAKS.

SINCE writing the paper under this title, which appeared in the June number of this journal, I have been in Milwaukee and had the opportunity of examining the oaks in two herbaria, probably representative of any that may be found there. In the Public Museum were two specimens labeled *Quercus palustris* Du Roi. One had an acorn, and as far as determinable by this and the leaf-characters, was *Q. ellipsoidalis;* it is certainly *not* what it is labeled. The other was without fruit, and was doubtless the same species. In the herbarium of Dr. LEWIS SHERMAN, one of the older residents of Milwaukee and an acquaintance of Dr. LAPHAM, was a specimen labeled as above. It had an acorn cup but no nuts. This showed at least that it was *not Q. palustris.* All the evidence tends to the conclusion that the real pin oak does not occur in the region from which these specimens were taken.—E. J. HILL, *Chicago.*

CURRENT LITERATURE.

BOOK REVIEWS.

Evolution.

A COMPREHENSIVE account of the subject of evolution is at present a matter of considerable importance, but at the same time must be one of unusual difficulty because of the great activity incited by the work of DE VRIES and others who have within the last few years undertaken the study of variation, adaptation, and heredity by experimental methods. Dr. J. P. LOTSY[1] has undertaken this most difficult task by the publication of a volume of lectures upon theories of descent with special reference to the botanical side of the question. He follows the method not infrequent among older writers but rare among writers of recent scientific works, of beginning at the beginning. He first considers the nature of knowledge, and the supposed conflict between science and religion, pointing out that evolution will not explain everything, and that there is no conflict between religion and science except as either or both attempt to explain dogmatically the unexplainable. Both science and religion come to the same conclusion when traced to their limit, namely, that there is a fundamental mystery incapable of investigation because none of the possible alternatives is even conceivable to the human mind.

After these two introductory lectures, one lecture is devoted to evolution in general, beginning with the origin of the earth, the evolution of minerals, the origin of life, and the relation of form to environment. Two lectures deal with the morphogenic stimuli and the various theories of direct response and adaptation. The views of REINKE and KLEBS are contrasted, and those of LAMARCK, SPENCER, NÄGELI, and WARMING are compared. Here the author gives a well-deserved appreciation of the work of LAMARCK, though he is not himself in any proper sense a Lamarckian. The subject of heredity is considered in six lectures, dealing first with the older theories of SPENCER, DARWIN, NÄGELI, and WEISMANN, which were of a purely hypothetical nature, and then taking up the development of our knowledge of chromosomes as the bearers of heredity. One whole lecture is devoted to MENDEL and his laws, two to variation curves and GALTON'S laws of inheritance, and one to numerous subsidiary questions, such as dominance and blending, atavism, kryptomery, pleiotypy, half races, etc., and one to the inheritance of acquired characters.

[1] LOTSY, J. P., Vorlesungen über Descendenztheorien mit besonderer Berücksichtigung der botanischen Seite der Frage, gehalten an der Reichsuniversität zu Leiden. Erster Teil. 8vo. pp. xii+384. *pls. 2. figs. 124.* Jena: Gustav Fischer. 1906. *M* 8; geb. *M* 9.

Discontinuous variation and mutation are treated in three lectures, and the six remaining lectures trace the history of the evolution idea from ARISTOTLE to DARWIN, the last lecture being devoted to the life of the latter.

A treatise on contemporaneous science is fraught with the same difficulties as attend the writing of contemporaneous history. A just estimate of the importance of the latest developments in either case only becomes possible in the light of subsequent development, and consequently a book of this kind might be expected to have a very evanescent value. LOTSY has avoided very much of this by taking a judicial attitude and treating his subject historically. He has depended to a very large extent upon quotations from the various scientists whose views or results he has presented, and this gives the reader something of the unpleasant sensation always given by a so-called "digest;" but his choice of quotations is good and his own language is simple and direct, and therefore easily followed.

A second volume is promised, in which is to be indicated the work still to be done, and this will be awaited with much interest, for it will be here that we may hope to gain more of the personality of the author. The present volume is exceptionally impersonal, and both gains and loses by this fact. If the second volume takes on the strength and virility of personal enthusiasm which incites to investigation, the lack of such qualities in this first volume may not be looked upon as a disadvantage. But even if it should indicate in the same dispassionate manner that characterizes this book, the problems awaiting solution, he will deserve the gratitude of every biologist. While this book can not be said to *fill* the need that called it forth, it is gratifying that the first attempt at filling it is so excellent. As the first comprehensive work dealing with the more recent phases of evolutionary study it should at once gain a deservedly large circulation.—GEORGE H. SHULL.

Chemistry of plants.

THE second volume of CZAPEK'S *Biochemie der Pflanzen* is a huge one,[2] and deepens the impression made by the first volume of the immense labor which such a compilation represents, and the equally immense service which the author has rendered to science in its preparation. For knowledge of the chemistry of plants has lagged far behind that of animals, which, under the stimulus of human relations through medicine, has been under constant investigation by many students.

This volume is devoted to (1) the proteids and their metabolism in various plants, (bacteria and fungi, mosses, algae, seeds, buds, leaves, roots, pollen grains) including the formation, absorption, and regeneration of proteids by various parts and under various conditions; (2) the nitrogenous end products of metabolism, including purin bases, glucosides yielding HCN, and alkaloids;

[2] CZAPEK, F., Biochemie der Pflanzen. Zweiter Band. 8vo. pp. xii+1027. Jena: Gustav Fischer. 1905. *M* 25.

(3) respiration and its products; (4) coloring matters other than chlorophyll and its associates; (5) mineral constituents; and (6) substances produced by stimulation. At the close is an appendix of 21 pages with many supplementary notes and corrections, bringing the data down to June 1905. A complete index renders available the rich store of information summarized in the text, and gives thus a clue to the literature of any substance or the chemistry of any group of plants.

The work is rather more than its title indicates, since it is pervaded by a strong physiological flavor. The chapter on respiration, indeed, is almost as much physiological as chemical, though it deals chiefly with the quantitative relations of the oxygen fixed and the various end-products of "oxidation."

With this work as a convenient register of the work heretofore done in plant chemistry, the progress of knowledge in this field ought to be much accelerated. Even though no such chemical work is in progress, every botanical laboratory, whether in experiment station or college, and every chemical laboratory, in connection with its courses or work in organic chemistry, needs this book for reference; while for public libraries it is as indispensable as an encyclopedia.—C. R. B.

MINOR NOTICES.

Mosses.—The third part of GROUT'S *Mosses with hand-lens and microscope* contains the families Encalyptaceae, Orthotrichaceae, Funariaceae, Bryaceae, Leskeaceae, and some of their smaller allies.[3] The Orthotrichaceae and Bryaceae are particularly difficult groups, and the admirably reproduced illustrations from the *Bryologia Europaea* and SULLIVANT'S *Icones* (with an occasional original figure) will be most helpful to amateurs who cannot own these costly works. The keys are clear and concise. The text might easily be improved by being made more formal, with the chatty matters reduced to notes in smaller type under the appropriate headings. But the clientèle to whom the work is addressed will not quarrel with this—until they become increasingly expert and seek data for which the space might have been used but is not. Then it will be time for them to lay aside these useful crutches and take up the technical works. It is a marvel that the author can furnish such numerous and good illustrations and well-printed letter-press at the price.—C. R. B.

Sylloge Fungorum.—Volume XVIII, Part VII of the Supplement of that monumental work of taxonomic mycology, Saccardo's *Sylloge Fungorum*, has recently been issued (January 30, 1906). This volume contains additions bringing as nearly up to date as possible the compilation of descriptions of the Discomycetae, Myxomycetae, Myxobacteriaceae, and Deuteromycetae. The last group, which constitutes the *Fungi Imperfecti* of the older volumes, occupies fully

[3] GROUT, A. J., Mosses with hand-lens and microscope, a non-technical handbook of the more common mosses of the northeastern United States. Part III. Imp. 8vo. pp. 167–246. *pls. 36–55. figs. 79–133.* Brooklyn, N. Y. The Author, 360 Lenox Road. 1906. $1.25.

two-thirds of the present volume. The work concludes with the usual "repertorium," index of species, and a complete index of genera in all volumes. The generic index is printed on differently colored paper. Some suggestions regarding the diagnosis and nomenclature of species printed in the first pages of the volume aim to bring about some uniformity in the publication of species. As these rules have been published in several journals,[4] it is unnecessary to repeat them here.—H. HASSELBRING.

A book for young gardeners.—A booklet prepared by H. D. HEMENWAY,[5] the director of the School of Horticulture at Hartford, Conn., will prove helpful to those interested in home and school gardens. Aside from simple discussion of the objects and benefits of tillage, the preparation of the soil, and planting the garden, the booklet furnishes abundant and detailed directions for testing and saving the seeds of the more common flowers and vegetables, for the planting of trees, the making of hot-beds, the making of window gardens, and for the culture of strawberries and other fruits. The directions are clear and give with sufficient detail the points most useful to the beginner.—H. HASSELBRING.

Das Pflanzenreich.—Part 25 of this work has just appeared[6] and contains a presentation of the Juncaceae by the late Dr. FR. BUCHENAU. The usual full discussion of the various structures of the family and its geographical distribution is followed by a synopsis of the 8 genera, among which the species are distributed as follows: Distichia (3), Patosia (1), Oxychloe (2), Marsippospermum (3), Rostkovia (1), Prionium (1), Luzula (61, of which 2 are new), Juncus (209, of which 5 are new). The whole presentation is remarkably full in details of forms and in illustrations, and is of particular interest to American botanists.—J. M. C.

Index Filicum.—The ninth fascicle of CHRISTENSEN'S work has appeared,[7] carrying the references from *Polypodium Beddomei* to *Polystichum aculeatum*. The great genus Polypodium fills the whole fascicle excepting the last page.—J. M. C.

NOTES FOR STUDENTS.

Plant diseases.—CLINTON,[8] in his report as Botanist of the Connecticut Experiment Station for 1905, presents interesting notes and illustrations of several fungous diseases of plants in that state, followed by a more detailed

4 In the United States, in Jour. Mycol. **10**:109. 1904.

5 HEMENWAY, H. D., Hints and helps for young gardeners, a treatise designed for those young in experience as well as youthful gardeners. 8vo. paper. pp. 59. illustrated. Hartford, Conn.: The Author. 1906. 35 cents.

6 ENGLER. A., Das Pflanzenreich. Heft 25, Juncaceae by FR. BUCHENAU. 8vo. pp. 284. *figs. 121 (777)*. Leipzig: Wilhelm Englemann. 1906. *M* 14.20.

7 CHRISTENSEN, C., Index Filicum, etc. Fasc. 9. Copenhagen: H. Hagerups Boghandel. 1906. 3*s*. 6*d*.

8 CLINTON, G. P., Report of the Botanist. Rept. Conn. Exp. Stat. **1905**: 263–330. *pls. 13–25. figs. 8–9.* 1906.

account of the downy mildew of the lima bean, due to *Phytophthora phaseoli*, and of the downy mildew or blight of the Irish potato, due to *Phytophthora infestans*. The two latter diseases are fully described and illustrated, and citations of the literature of each disease are given.

WHETZEL[9] gives an illustrated account of the following bean diseases found in New York state: anthracnose, due to *Colletotrichum lindemuthianum*; blight, due to *Bacterium phaseoli;* and rust, due to *Uromyces appendiculatus*. Methods of treatment are also given in each disease.

SHELDON[10] has just published the results of his study of the ripe rot or mummy disease of guavas. This disease is similar in many respects to the ripe rot or bitter rot of apples. It is produced by *Glomerella psidii* (G. Del.) Sheldon. He found the ascigerous stage and worked out the life history of the fungus in considerable detail.

NORTON[11] has published a brief summary of the present knowledge of the diseases of the Irish potato in Maryland together with methods of treatment of these diseases.

STEVENS[12] in his report as Biologist of the Experiment Station of North Carolina gives the results of his experiments in soil treatment for the prevention of the Granville tobacco wilt. He concludes that the greatest hope of overcoming this serious trouble lies in the breeding and selecting of resistant strains of tobacco, and he is now engaged in this line of work.

SMITH[13] presents preliminary observations regarding three serious diseases of tomatoes in California. The first is the damping off of the young seedlings. It is suggested that to check the spread of this trouble the plants and soil be sprayed with weak Bordeaux mixture followed with a sprinkling of sulfur. Soil sterilization by means of live steam would no doubt control it in cases where the application of this remedy is possible. The second disease mentioned is the summer blight, due to a species of Fusarium which attacks the plant in much the same manner as does the fusarium stage of Neocosmospora which causes the wilt of cotton, etc. The third disease mentioned is the winter blight, due to the potato-blight fungus, *Phytophthora infestans*. It occurs only after heavy fogs, dews, or rains, and hence in California attacks only the winter crop. Spraying with Bordeaux mixture is recommended to be applied just after the rains or dews.

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[9] WHETZEL, H. H., Some diseases of beans. Bull. N. Y. Cornell Exp. Stat. 239:195–214. *figs. 100–114*. 1906.

[10] SHELDON, J. L., The ripe rot, or mummy disease of guavas. Bull. W. Va. Exp. Stat. 104:299–315. *pls. 1–4. fig. 1*. 1906.

[11] NORTON, J. B. S., Irish potato diseases. Bull. Md. Exp. Stat. 108:63–72. *figs. 1–4*. 1906.

[12] STEVENS, F. L., Report of the Biologist. Rept. N. Car. Exp. Stat. **1904**: pp. 10. 1905.

[13] SMITH, R. E., Tomato diseases in California. Bull. Calif. Exp. Stat. 175: 1–16. *figs. 1–8*. 1906.

REED[14] has described three fungous diseases of the cultivated ginseng. These diseases are not due to the same fungi reported by VAN HOOK[15] as causing ginseng diseases in New York. The first of these is a stem anthracnose due to *Vermicularia dematium*. The second is a leaf anthracnose due to *Pestalozzia funeria*. These two diseases he finds may be controlled by spraying with the usual Bordeaux mixture. The third disease described is a wilt due to *Neocosmospora vasinfecta nivea*. This same variety causes a wilt disease of the watermelon, while the species itself causes a wilt disease of cotton and the cowpea. REED finds that the wilt never occurs except in association with or following an attack of the stem anthracnose. In other words, the wilt fungus seems to be able to gain entrance to the ginseng plant through the lesions on the stem due to this other stem disease. It is also possible that the wilt fungus enters the plant at the scar left where the stem of the preceding year fell off. It should be recalled in this connection that the cotton and cowpea wilt-fungus enters the host through the roots largely after injury by the nematode worm.—E. MEAD WILCOX.

SORAUER[16] describes a peculiar disease of *Cereus nycticalis* Lk. which results from proliferation of cells of the inner layers of the cortex. This produces on the stems slightly elevated hygrophanous areas which increase in size until they occupy a large part of the stem and extend to the wood. These turn brown and then black and finally collapse, leaving depressed wounds in the stem. On account of the position of the proliferating cells SORAUER designates these growths as "internal intumescences." The diseased regions are almost free from starch, but they are rich in glucose, which the writer regards as the cause of the unusual growth. This condition is brought about by high temperature and excessive moisture. When these factors were changed no "intumescences" were formed. —H. HASSELBRING.

The maturation mitoses.—A critical review of the entire subject of the maturation mitoses in both plants and animals has been prepared by GRÉGOIRE.[17] Part I, dealing with stages from the metaphase of the first mitosis in the mother-cell up to the telophase of the second division, contains 155 pages and 147 text figures, of which 35 pages and 35 figures relate to sporogenesis in plants, 90 pages and 112 figures to spermatogenesis and oogenesis in animals, and the remaining 30 pages to a comparative study. The space given to animal mitoses increases the value of the work to botanists, who are already more or less familiar with the botanical literature. At the close of the botanical section the conclusion

[14] REED, H. S., Three fungous diseases of the cultivated ginseng. Bull. Mo. Exp. Stat. 69:41–66. *figs. 1–9.* 1905.

[15] VAN HOOK, J. M., Diseases of ginseng. Bull. N. Y. Cornell Exp. Stat. 219: 163–186. *figs. 18–42.* 1904.

[16] SORAUER, P., Zeitr. Pflanzenkrankheiten **16**:5–10. *pl. 2.* 1906.

[17] GRÉGOIRE, VICTOR, Les resultats acquirés sur les cinèses de maturation dans les deux règnes. Premier mémoire. Revue critique de la littérature. La Cellule **22**:221–376. *figs. 147.* 1905.

is reached that the definitive chromosomes of the first mitosis constitute two branches which are variously placed with relation to each other. These two branches are the daughter chromosomes of the first mitosis. During the metaphase or anaphase these daughter chromosomes split longitudinally. In the telophase no complete spirem is formed nor do the nuclei reach the resting condition, but the chromosomes preserve their individuality so that the longitudinal portions which appeared in the anaphase of the first mitosis become the daughter chromosomes of the second mitosis. Consequently, the second mitosis cannot be a reduction division. Whether a reduction takes place at the first mitosis will be discussed in the second memoir. In the general résumé the conclusion is reached that in both plants and animals the definitive chromosomes of the first mitosis, at the equatorial plate stage, are composed of two continuous branches. There are two categories of theories as to the significance of the second mitosis, the one holding it as an equation division and the other as a reduction division.

In regard to the two constituent branches of the chromosomes of the first mitosis, there are two possibilities: if they are longitudinal pieces of a segment of a primary chromosome, the heterotypic division is an equation division; if, on the other hand, each of the two branches is a complete somatic chromosome, there is a true reduction in the WEIS MAN sense. The important question is, How are the chromosomes of the first mitosis formed? This will be the subject of the second memoir.

The work will be welcomed by cytologists, for the subject matter is well arranged and conflicting theories are impartially discussed. While the title indicates only a critical review of the literature, the work is something more, because so much botanical investigation has been done in the writer's own laboratory, and because even the zoological section has not been written entirely from the literature, but from the writer's own preparations and numerous preparations loaned by prominent investigators of animal cytology.—CHARLES J. CHAMBERLAIN.

Nova in hybrids.—As has been already noted[18] in these pages, TSCHERMAK found a large number of instances in which *nova* appeared in hybrid beans and peas, in very definite ratios which were readily related to the ordinary Mendelian ratio. These *nova* were explained by him as characters latent in one of the parental strains, but rendered patent by the energizing effect of the cross-fertilization. CORRENS has adopted[19] for similar *nova* in Mirabilis the hypothesis of CUENOT, which makes such new characters the result of the combined action of two or more pairs of units, the positive member of some or all but one of these pairs of units being invisible because of the absence of the other member of the combination. For example, an albino mouse bred with a brown mouse may produce black offspring, because the albino contains a unit which

[18] See BOT. GAZETTE 39:302. Apr. 1905.

[19] See BOT. GAZETTE 40:234. Sept. 1905.

has the power of changing the gray pigment to black, but this pigment-changing unit will remain invisible so long as the albino is bred only with other albinos.

Under this conception the *novum* is a compound character formed by the combination of equivalent units, instead of a hitherto inactive character rendered active by the stimulating effect of a foreign plasma. TSCHERMAK[20] now assents to the explanation of CUENOT and CORRENS as valid in certain cases, but still maintains that the *nova* of his *Pisum arvense* × *sativum* crosses and others cannot be so explained, because he found no cases in which the offspring were not *all* cryptomeric. TSCHERMAK's reference to the fact that the *nova* are frequently of atavistic nature, as lending support to GALTON's "law of natural inheritance," will scarcely be approved, since the explanation of CUENOT and CORRENS would bring these into agreement with typical Mendelian hybrids.

BATESON[21] has likewise adopted the explanation of CUENOT and CORRENS in the interpretation of *nova* in sweet peas and stocks which had been presented[22] in the Second Report to the Evolution Committee, as wholly out of harmony with Mendelian inheritance. These now constitute exceptionally good examples of characters which can only become manifest when two or more units act together. The statement is made that most of the five gametically distinct types which should appear among the white sweet peas and white stocks of these crosses have been recognized, thus answering satisfactorily, in respect to these two species, TSCHERMAK's contention that the extracted whites were still cryptomeric.

The same explanation is clearly valid for the case reported by CASTLE[23] in which a white guinea-pig crossed with red gave rise to some black offspring, while the "extracted" whites from this cross, when crossed with red, produced no black young.—GEORGE H. SHULL.

Welwitschia.—The full paper on *Welwitschia mirabilis* by PEARSON has now appeared,[24] the abstract of last November having been noted in this journal.[25] The region of this strange plant is so difficult of access that Professor PEARSON is to be commended for the unusual efforts he has put forth to secure material. As it happened, the war in Africa has seriously interfered with his work, so that he was able to secure material of only one day's collecting, but he hopes that when the country becomes more settled he will be able to fill in the gaps.

[20] TSCHERMAK, E., Die Mendelsche Lehre und die Galtonsche Theorie vom Ahnenerbe. Arch. f. Rass. u. Gesells. Biol. **2**:663–672. 1905.

[21] BATESON, W., SAUNDERS, E. R., and PUNNETT, R. C., Further experiments on inheritance in sweet peas and stocks: Preliminary account. Proc. Roy. Soc. London B. **77**:236–238. 1905.

[22] See BOT. GAZETTE **40**:313–314. 1905.

[23] See BOT. GAZETTE **40**: 385. 1905.

[24] PEARSON, H. H. W., Some observations on *Welwitschia mirabilis* Hooker. Phil. Trans. Roy. Soc. London B. **198**:265–304. *pls. 18–22.* 1906.

[25] BOT. GAZETTE **41**:226. 1906.

The plant is of such unusual interest that his results deserve rather full statement.

The maximum age attained by individual plants is probably much greater than a century; and plants growing in contact readily form natural grafts, into the composition of which several individuals may enter. Pollination is effected, partly, at least, by insects. The development of the spores and of the embryo proceed with remarkable rapidity for a gymnosperm. Microsporogenesis resembles that described for Ephedra and Gnetum; and at dehiscence three nuclei are found in the pollen grain, one of which, probably prothallial, disappears before shedding. The single megaspore mother cell forms the usual linear tetrad, the innermost spore functioning. In the germination of the megaspore there is abundant free nuclear division, and a strong growth of the sac towards the micropyle and into the chalazal region. The formation of cell walls occurs throughout the embryo sac, the cells thus formed often being multinucleate. Each peripheral cell towards the micropyle, containing two to five nuclei, produces a tubular outgrowth which penetrates the nucellar cap like a pollen tube. As this tube advances the nuclei pass into it, and the distance traversed before pollination occurs is considerable. These free nuclei are sexual, and hence the condition is that of Gnetum. These tube-forming cells have been taken for archegonium initials, but it is evident that the tube is only an extension of the prothallium containing free sexual nuclei; and hence PEARSON rightly calls it the "prothallial tube." This is a most satisfactory disposition of a troublesome structure; and we find that in the act of fertilization Welwitschia is even more specialized than is Gnetum.

It is to be regretted that the first stages of embryo-formation were not shown by the material, for the current statements in reference to it are as obscure and meaningless as have been those in reference to the so-called "archegonium initials."—J. M. C.

Mendelism in agriculture.—No other single scientific proposition has elicited so much interest from agriculturists and breeders as MENDEL's laws of inheritance, and the number of more or less satisfactory popular presentations has become large. Several of these have already been noted. TSCHERMAK[26] adds another in a lecture before the German Agricultural Society, in which particular attention is given to the results in the breeding of cereals. Besides the general explanation of Mendelism, he gives tables showing what characters of the several cereals have been found dominant and what recessive. These tables include sixteen pairs of characters in wheat, five in rye, thirteen in barley, and three in oats. A short section is devoted to the technic of crossing, and another to the importance of establishing stations and properly equipping them for carrying on such investigations.

[26] TSCHERMAK, E., Die Kreuzung im Dienste der Pflanzenzüchtung. Jahrb. Deutsche Landw. Gesells. **20**:325–338. 1905.

HALSTED[27] has also issued a bulletin which gives a good general discussion of Mendelism as exemplified by cooperative experiments in the breeding of corn. In 1904 "Black Mexican" sweet corn was crossed with nearly a full list of the commercial varieties of sweet corn, and the hybrid ears thus obtained were sent to a number of volunteer observers in different parts of the state, who returned samples and notes which are incorporated into this bulletin. The presentation is simple and easily understood, but several unfortunate typographical errors are likely to prove confusing, as when on p. 15 in the table showing what may be expected in the second generation of a cross between large grained flint black, and small grained sweet white, the fourth category (large sweet white) is weighted with the value 9 instead of 3; and again, when on p. 21, line 7, "white" is used for "dark."

An improper emphasis is laid upon the difficulty of freeing the dominant form from traces of the recessive. Thus, he says that after nineteen generations of selection there will still be one recessive grain in each four hundred, adding that "this underlying rule," which appears to hold more or less closely, helps to indicate how difficult it is to eradicate entirely any characteristic that has been introduced in breeding." He seems to have overlooked the importance of VILMORIN's principle of isolation, by which it requires only one more generation to obtain pure extracted dominants than extracted recessives, so that after the *third* generation he need never have another recessive grain appear.—GEORGE H. SHULL.

Inheritance in Shirley poppies.—PEARSON and his associates, with the aid of a number of volunteer observers, have presented a second paper[28] on inheritance in the Shirley poppy. Some of the questions that were left open in the earlier report[29] have been settled. Thus, it was assumed that Shirley poppies both self- and cross-fertilize, and the discussions were based upon that assumption. It is now found that when flowers are enclosed in bags of bolting-cloth or oiled paper, almost no fertilization takes place. Fifty bagged flowers produced seeds in only four, and these gave rise to nine plants. The conclusion is reached, therefore, that seeds taken from unprotected capsules are essentially the result of cross-fertilization; and the correlation of offspring with each other and with their antecedents should be the same as in other populations in which self-fertilization does not occur, as in animals and man. Although the correlation found is somewhat lower than the average for animals, a number of modifying factors are pointed out which would tend to lessen the correla-

[27] HALSTED, B. D., Breeding sweet corn—cooperative tests. N. J. Agr. Exp. Sta. Bull. 192. pp. 30. *pls. 4, figs. 8.* March 1906.

[28] PEARSON, K., et al., Cooperative investigations in plants. III. On inheritance in the Shirley poppy. Second Memoir. Biometrika 4:394–426. 1 *pl.* (colored). 1906.

[29] PEARSON, K., et al., Cooperative investigation in plants. I. On inheritance in the Shirley poppy. Biometrika 2:56–100. 1902.

tion, and the opinion is expressed that there is no reason to believe that the strength of inheritance is any different in Shirley poppies from that in animals.

Another gain is seen in the recognition of the entire plant as the hereditary unit, instead of the separate flowers, the latter view having been maintained in the earlier paper.

The characters used were the number of stigmatic bands, number of petals and petaloid stamens, color of petals, presence of a margin, presence of a basal spot and its color, and wrinkling of the petals. Each of these characters was divided into a number of categories designated in a manner that makes the personal equation a very large factor, *e. g.* with reference to the presence of a basal spot, the classes are "none, none to slight, slight, slight to well-defined, well-defined, well-defined to large, large." The observers found these categories very difficult to separate, and think there is no evidence of allelomorphic characters. They believe that the same is true in many studies made by those who accept MENDEL'S laws of inheritance. It need scarcely be pointed out that seeds secured from unguarded flowers from a field as heterogeneous as one of Shirley poppies could hardly be expected to show evidences of allelomorphic characters.—GEORGE H. SHULL.

Drying of seedlings and sporelings.—RABE finds that germinated seeds and spores resist drying more or less well.[30] With advancing germinative stages and exhaustion of reserve food the resistance to drying diminishes. Seedlings will withstand much longer drying in the air than in a sulfuric acid desiccator. The separated hypocotyl of a seedling always dies upon being fully dried out. The cotyledons are more resistant than the plumule, and of the latter the growing point and the axillary buds are more resistant than the leaves. The separated and dried portions of the seedling, if they are yet alive, are as vigorous in reproducing as the separated portions of the fresh seedling. In spite of the defective storage and marked shrinkage, the seedling of the unripe seed will withstand drying nearly as well as the seedling of the ripe seed. Seedlings of xerophytes are more resistant to drying than those of hydrophytes. The presence of the seed coat is a disadvantage to the dried seedling. Rapid admission of water is more advantageous to the dried seedling than slow admission. Seedlings of related species show no relation in their power to withstand drying. Water-free chemical reagents, as alcohol and benzene, act more harmfully on germinated dried seedlings than on ungerminated dried seeds. The germinated dried as well as the ungerminated soaked seeds are more injured by diluted than by concentrated glycerin. The longer the glycerin acts the greater the injury. The germinated spores of mosses are extremely resistant to drying whether in the air or in a sulfuric acid desiccator. Germinated spores of ferns and liverworts withstand but little drying. The power of plants to withstand drying depends mainly upon the peculiar properties of their protoplasm.—WM. CROCKER.

[30] RABE, FRANZ, Ueber die Austrocknungsfähigkeit gekeimter Samen und Sporen. Flora 95:253–324. 1905.

Anatomy of Cyperaceae.—The comparative anatomy of the Cyperaceae has been studied by PLOWMAN,[31] and as usual the chief interest centers in the stem. Amphivasal bundles are found throughout the rhizomes of all large-leaved species and at the nodes of aerial stems; elsewhere the bundles are collateral. The amphivasal bundles arise through the introduction into the node of the numerous leaf-trace bundles, and are independent of the branching of the stem. Hence the leaf is to be regarded as the dominant factor in the development of the stelar characteristics of the family and probably of the other monocotyledonous families. The course of the bundles in the rhizome approaches the "palm type," but in the culm the leaf-trace bundles pass down as cortical bundles through one internode and then fuse with the bundles of the central cylinder by a ring-like amphivasal plexus. The seedling and in some cases the floral axis show a simple tubular stele, which is to be regarded as the primitive condition, in contrast with the medullary and amphivasal bundles occurring in many parts of the plant. A cambium is present in the bundles at the nodes of *Scirpus cyperinus* and other species. These features indicate that the Cyperaceae is one of the more primitive groups of monocotyledons, though showing signs of specialization and reduction, accompanied by a high degree of anatomical unity. The view which derives the monocotyledons from an essentially dicotyledonous ancestry receives further support. The author proposes a division of the family into "Amphivasae" and "Centrivasae;" he also gives a key to the genera, based on anatomical characters. The paper is accompanied by a number of excellent photomicrographs.—M. A. CHRYSLER.

Origin of Cycadaceae.—WORSDELL[32] has published a *résumé* of his views as to the origin of the Cycads from the Pteridosperms, with full bibliography. The part dealing with the origin of axial structures is of greatest interest; and the thesis is that the Medullosan ancestry is clear. It is claimed that the cotyledonary node and the axis of the strobilus are the two principal regions for revealing ancestral characters. Much stress is laid upon MATTE'S discovery of polystely in the cotyledonary node of *Encephalartos Barteri;* and also upon the very irregular orientation of the bundles of the peduncle of Stangeria. According to the author's view, the endarch cylinder of Lyginondedron and of the Cycads is of polystelic origin, coming from Medullosan ancestors, each constituent bundle being the homologue of the single bundle of the monostelic Heterangium. The endarch condition arises from the degeneration of the internal vascular tissues. Numerous illustrations are given, intended to show how the various vascular structures of both Pteridosperms and Cycads suggest this view and are most easily explained by it. The whole presentation is

[31] PLOWMAN, A. B., The comparative anatomy and phylogeny of the Cyperaceae. Annals of Botany **20**:1–33. *pls. 1–2.* 1906.

[32] WORDSELL, W. C., The structure and origin of the Cycadaceae. Annals of Botany **20**:129–159. *figs. 17.* 1906.

particularly valuable in bringing scattered data together in compact form, although opinions may vary as to their interpretation.

A new term of classification is introduced with "Cycadophyta," used to include Pteridosperms (Cycadofilices), Bennettitales, and Cycadales. The author also discredits somewhat the value of the ontogeny of the vascular structures as indicating their phylogeny.—J. M. C.

Osmosis and osmotic pressure.—A revolutionary paper upon the nature of osmosis and osmotic pressure has been published by KAHLENBERG,[33] who gives detailed accounts of his experiments. He shows clearly that whether osmosis will take place or not depends upon the specific relations between the septum and the liquids bathing it. If osmosis occurs these relations determine the magnitude of the pressure and the direction of the main current. There is, he claims, no such thing as a strictly semipermeable membrane, since a minor movement in the reverse direction always occurs, though it is often insignificant or practically negligible. The force concerned in osmotic processes lies not merely in the specific affinities between the solvent and the solutes, but primarily in their relation to the membrane, whether it be called "potential energy of solution," "internal pressure," or (as KAHLENBERG prefers) "chemical affinity." In measuring osmotic pressures (for which he devised a new apparatus), stirring the liquids is absolutely essential—a factor not previously reckoned with; and in his experiments these measurements show such unlike pressures with the same substances when different membranes are used, and such changes with different temperatures that he holds them irreconcilable with the theory that, as a general rule, solutes conform to the behavior of gases, however closely some in water may do this. The paper deserves the closest attention from every physiologist; yet the weighty evidence against KAHLENBERG'S conclusions must not be forgotten.—C. R. B.

The vitality of buried seeds.—DUVEL gives a preliminary account of experiments on the vitality of buried seeds,[34] of some of the common economic plants and weeds of the United States, representing 109 species, 84 genera, and 34 families. In December, 1902, eight to twelve lots of each species of seeds were buried at three depths: 15–20, 46–56, 90–105 ^{cm}. A sample of each is to be taken up at given periods and tested for vitality along with controls stored in a dry place.

Tests up to date show the following results. In some cases none of either the controls on the buried seeds grow. Among these are: *Axyris amaranthroides, Bursa bursa-pastoris, Polygonum pennsylvanicum, P. persicaria, P. scandens.*

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33 KAHLENBERG. L., On the nature of the process of osmosis and osmotic pressure, with observations concerning dialysis. Journ. Phys. Chem. 10:141–209. 1906. Published also in Trans. Wis. Acad. 15:209–272. 1906.

34 DUVEL, J. W. T., Vitality of buried seeds. Bureau Plant Industry Bull. 83. pp. 22. *pls. 3.* 1905.

A second group, among which are the common cereals and various other plants, as *Lactuca sativa*, *Helianthus annuus*, *Asparagus officinalis*, *Pinus virginiana*, *Robinia pseudacacia*, either all decayed before germinating or germinated and then all decayed before being examined. A third group, which includes our more noxious weeds, retained their vitality to a considerable degree. The deeper the seeds were buried the better they retained their vitality. Vitality is best preserved, even in weed seeds, when they are carefully harvested and stored in a dry and comparatively cool place.—WM. CROCKER.

Prothallia and sporelings of Botrychium.—BRUCHMANN[35] has been investigating *Botrychium Lunaria*. Since this species has no means of vegetative multiplication, like the adventitious shoots of *Ophioglossum vulgatum*, every sporophyte must have come from a gametophyte. The prothallia are hard to find because they are very small (1–2^{mm} long and 0.5–1^{mm} wide), and the sporelings grow for several years before they reach the surface of the soil. The prothallia are found at a depth of 1–3^{cm}. In form and general character the prothallium of *B. Lunaria* resembles that of *B. virginianum*, except that it is much smaller. BRUCHMANN succeeded in germinating the spores and his results agree with those of CAMPBELL, who got the two and three-cell stage in *Ophioglossum vulgatum*. Further work upon this aspect of the problem will be published later. However, he represents a single cell at the "spore pole" of the prothallium and regards this as the first cell of the prothallium, representing the protonema stage. Nearly every prothallium bears an embryo and some prothallia have two. The first division of the embryo is transverse. Growth is very slow, the sporeling being three years old before it reaches the surface. One plate and considerable attention in the text is devoted to the anatomy of the mature plant.—CHARLES J. CHAMBERLAIN.

Spermatozoids of Cycas revoluta.—MIYAKE[36] studied the living spermatozoids at the island of Oshima (28° 30′ N) in September, and in southern Japan (31° 35 N) from the beginning to the middle of October. The diameter of the spermatozoids varies from 180 to 210 μ. The two spermatozoids are surrounded by a delicate membrane, but it could not be determined with certainty whether the membrane belongs to the spermatozoid or is merely the *Hautschicht* of the protoplasm of the pollen tube. For observing the movements the spermatozoids were placed in a 10 per cent. cane sugar solution. The movements often continued for one to three hours; and in one case for six hours and forty minutes, and in another case for five hours and thirty minutes. In some cases the spermatozoids were shot out suddenly from the pollen tube, which seems to be the method that occurs under natural conditions. The forward movement is always accompanied by a rotation from left to right about the

[35] BRUCHMANN, H., Ueber das Prothallium und die Sporenpflanze von *Botrychium Lunaria* Sw. Flora **96**:203–230. *pls. 1–2.* 1906.

[36] MIYAKE, Ueber die Spermatozoiden von *Cycas revoluta*. Ber. Deutsch. Bot. Gesell. **24**:78–83. *pl. 6.* 1906.

axis. In some cases the forward movement was found to be at the rate of 0.7^{mm} per second. MIYAKE agrees with WEBBER that the liquid in the archegonial chamber at the time of fertilization comes from the pollen tube and not from the archegonium.—CHARLES J. CHAMBERLAIN.

Heterostyly and gynodioecism.—Inheritance of dimorphism has been investigated by RAUNKIÄR[37] in Primula, Menyanthes, Pulmonaria, Fagopyrum, Knautia, and Thymus. In all heterostylic species studied he finds that the long-styled and short-styled forms occur in about equal numbers regardless of the character of the environment. In gynodioecious species, on the other hand, he finds considerable variation in the proportions of the two forms in different localities. The results of breeding are in close accord with those of CORRENS,[38] except in an interesting case in which a cross between two bisporangiate plants of *Thymus vulgaris* produced 65 per cent. pistillate plants. In *Primula officinalis*, brachystylic plants pollinated by brachystylic produced 62.5 per cent. brachystylic, brachystylic×dolichostylic gave 55.2 per cent. brachystylic, and dolichostylic×dolichostylic only 4.3 per cent. brachystylic. Investigation covering several generations is needed to determine the effects of the pre-parental ancestry, and until this is done, any speculation as to the hereditary nature of the forms of a dimorphic species can be of little value.—GEORGE H. SHULL.

Development of spores of Helminthostachys.—BEER[39] has investigated the development of the spores of H. *zeylanica*, his material being fertile spikes preserved in spirit. CARDIFF,[40] and afterwards STEVENS,[41] had described the peculiar blocking out of the sporogenous tissue and the remarkable behavior of the plasmodium-like tapetal cytoplasm in Botrychium; and BEER finds the same phenomena in Helminthostachys. His observations extend, however, to the specific work of the tapetal plasmodium in spore-formation. The observed facts are that during the period of exospore growth the tapetal plasmodium shows more or less complete disappearance of starch, gradual diminution of the finely vacuolar cytoplasm, and richly chromatic nuclei which often show irregularities of outline. The conclusion is that the tapetal plasmodium is the center of metabolic activities in which a substance is elaborated from the raw materials contained in the tapetum, and is employed, directly or indirectly, in the growth of the spore wall.—J. M. C.

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37 RAUNKIÄR, C., Sur la transmission par hérédité dans les espèces hétéromorphes. Bull. Acad. Roy. Sci. et Let., Denmark, pp. 31–39, 1906.

38 See BOT. GAZETTE **39**: 304. 1905. and **41**: 302. 1906.

39 BEER, RUDOLF, On the development of the spores of *Helminthostachys zeylanica*. Annals of Botany **20**:177–186. *pls. 11–12.* 1906.

40 BOT. GAZETTE **29**:340–347. *pl. 9.* 1905.

41 Annals of Botany **19**:—. —. 1905.

Seedlings of Piperales.—In continuing his work on the structure of the seedlings of certain Piperales, HILL[42] has published results dealing chiefly with several species of Peperomia. The transition phenomena are described in detail; that is (in brief), the arrangement of the vascular tissues in the cotyledonary or primary node, the transition region between root and stem, where the earliest tissues of the vascular system arise. The conclusion in reference to the primitive or reduced character of Peperomia is confirmatory of JOHNSON'S view that it is a reduced genus, the determining factor in reduction possibly being the epiphytic habit of many forms. It is also suggested that these transition phenomena may not be such important phylogenetic criteria as has been assumed by some investigators, since they do not seem to be sufficiently rigid to withstand the influence of varying conditions.—J. M. C.

Antipodal cells.—In a long article LOTSCHER[43] discusses the structure and function of the antipodal cells of angiosperms. On the basis of their anatomy and physiology he finds three types of antipodals: (1) those remaining as naked protoplasts or free cells and functioning in the resorption of the nucellus (Orchidaceae, Cruciferae, Geraniaceae, Linaceae, Papilionaceae, Primulaceae, Polemoniaceae, and Scrophulariaceae); (2) those well differentiated and forming a roundish cell-complex which serves to transform the foodstuffs which are brought to the embryo-sac (Gramineae, Araceae, Ranunculaceae, Mimosaceae, Cesalpinaceae, and in combination with the third type, predominant in Liliaceae, Iridaceae, Zingiberaceae, Borraginaceae, and Solanaceae); (3) those, singly or together, having an elongated form and functioning principally as haustoria (most Rubiaceae).—CHARLES J. CHAMBERLAIN.

Mechanics of secretion.—This problem has been attacked by LEPESCHKIN, who finds[44] that from "unicellular" plants (Pilobolus, Mucor, Phycomyces, and Vaucheria are so called), as well as from the epidermal structures of green plants, secretion is to be referred to the unlike permeability for solutes of the plasma membrane in the absorbing and secreting regions of the structure. The process of secretion and the influence of external agents upon it agree completely with the mathematical formulae for the energy involved, based upon the current theories of osmotic pressure. The permeability of the membrane is easily altered by external and internal influences. Whether this is characteristic of all semipermeable membranes or only of plasmatic membranes remains to be determined. The research adds some facts but leaves much yet to be explained regarding the subject.—C. R. B.

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[42] HILL, T. G., On the seedling-structure of certain Piperales. Annals of Botany **20**:160–175. *pl. 10.* 1906.

[43] LOTSCHER, P. KONRAD, Ueber den Bau und die Funktion der Antipoden in der Angiospermen-Samenanlage. Flora **94**:213–262. *pls. 1–2.* 1905.

[44] LEPESCHKIN, W. W., Zur Kenntniss des Mechanismus der aktiven Wasserausscheidung der Pflanzen. Beihefte Bot. Cent. **19**:409–452. 1906.

Pollen grains of Picea.—POLLOCK[45] has described variations observed in the pollen grain structures of *Picea excelsa*, chiefly in reference to the so-called prothallial cells. The usual number of these cells reported for the Abietineae is two, but POLLOCK finds the variation in Picea to range from one to three, with one as the number in the majority of cases. This is an interesting situation, as these cells have been reported thus far for the conifers only among the more primitive Abietineae and Podocarpeae, and it shows that even here they are in a very fluctuating condition. The condition among the Araucarias, recently announced by THOMSON, is interpreted as representing a still greater multiplication of prothallial cells, an interpretation that is probably justified. That among the conifers all stages in the elimination of this tissue are represented seems evident.—J. M. C.

Sclerotinia on Forsythia.—OSTERWALDER[46] has described a disease of species of Forsythia induced by *Sclerotinia Libertiana* which has heretofore been reported only upon herbaceous plants. The fungus infects the shoots of Forsythia only through the withering flowers, and extends up and down the woody branches from those points, causing a wilting of the twigs alone. Sclerotia are formed abundantly on the infected parts and after being kept over winter produce the typical apothecia of Sclerotinia. Spores or mycelium grown therefrom produced the disease anew when placed on the floral parts. Although Botrytis conidiophores occurred on some of the withered flowers, the author was able to show that these were not connected with the Sclerotinia, thereby supporting the view that *Sclerotinia Libertiana* has no conidial form.—H. HASSELBRING.

A sterile Bryonia hybrid.—In studying the development of the sex organs of a sterile hybrid of *Bryonia alba* and *B. dioica*, TISCHLER[47] comes to the conclusions that the absolute sterility has nothing to do with the tetrad formation because the megaspore series shows the normal tetrads, and that while there are irregularities in the formation of pollen there are also cases in which normal pollen is formed. It is possible that the cause of sterility in hybrids is more complicated than has been supposed. This work does not support the theory that sterility is due to total or partial loss of power by the male or female chromosomes. It may be that the sterility is due to a low nutrition of the protoplasm. It seems probable that the cause of sterility can best be investigated by combining culture methods and cytology.—CHARLES J. CHAMBERLAIN.

Photosynthesis.—USHER and PRIESTLEY have contributed strong support to the theory of BAEYER that formaldehyde is the first product of photolysis of CO_2.

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45 POLLOCK, JAMES B., Variations in the pollen grain of *Picea excelsa*. Amer. Nat. 40:253–286. *pl. 1.* 1906.

46 OSTERWALDER, A., Die Sclerotienkrankheit bei den Forsythien. Zeitsch. Pflanzenkr. 15:321–329. *pl 5.* 1905.

47 TISCHLER, G., Ueber die Entwicklung der Sexualorgane bei einem sterilen Bryonia-Bastard. Ber. Deutsch. Bot. Gesell. 24:83–96. *pl. 7.* 1906.

They find[48] an enzyme in spermatophytes and pteridophytes generally, which decomposes H_2O_2 energetically, with the evolution of O_2. When this enzyme is destroyed or its action inhibited, the chlorophyll is quickly destroyed and the plant bleached. They also demonstrated the formation of formaldehyde (when its prompt condensation was prevented) in the immediate vicinity of the chloroplasts. The usual condensation of the HCOH is due, they hold, to the protoplasmic stroma of the chloroplast and not to an enzyme; yet the experiment on which they rely is not conclusive on this point.—C. R. B.

Seeds of Euphorbiaceae.—A study of the development of the seeds of numerous genera and species of Euphorbiaceae has given SCHWEIGER[49] the following results: The obturator, a tissue which serves for the conduction and nutrition of the pollen tube, is always present. It disappears gradually after fertilization, leaving only a slight remnant which belongs to the placenta and never to the seed. The tip of the nucellus is often much elongated, and until fertilization is effected is often in direct connection with the obturator. The caruncle belongs to the seed, is developed from the outer integument, and serves to separate the seed from the placenta.—CHARLES J. CHAMBERLAIN.

Zygospores of Mucor.—According to HAMAKER[50] the production of zygospores of *Mucor stolonifer*, with proper conditions of moisture and temperature, is dependent only upon the nature of the substratum. The atmosphere should be saturated with moisture and the temperature about 70° F. The substratum used is corn muffin bread, which the baker makes after the following formula: corn meal, 16 pounds; flour, 3 pounds; lard, 3 pounds; salt, ½ pound; eggs, 48; sweet milk, 3 gallons; baking powder, 18 ounces. In a large proportion of cultures zygospores appear in five to seven days.—CHARLES J. CHAMBERLAIN.

Germination of pollen.—JOST has succeeded in germinating the pollen grains of various grasses,[51] which have heretofore proved refractory, by growing them under conditions where they can obtain water very slowly from the medium by which it is held. Thus, a starch paste made with only one or two parts of water proved useful; and also parchment paper soaked with a sugar solution. The pollen grains of certain Compositae have also yielded to the latter treatment, but none of the Cichoriaceae or Umbelliferae.—C. R. B.

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48 USHER, F. L., and PRIESTLEY, J. H., A study of the mechanism of carbon assimilation in green plants. Proc. Roy. Soc. London B. **77**:369–376. 1906.

49 SCHWEIGER, JOSEPH, Beiträge zur Kenntniss der Samenentwickelung der Euphorbiaceen. Flora **94**:339–379. 1905.

50 HAMAKER, J. I., A culture medium for the zygospores of *Mucor stolonifer*. Science N. S. **23**:710. 1906.

51 JOST, L., Zur Physiologie des Pollens. Ber. Deutsch. Bot. Gesells. **23**:504–515. 1906.

Dry rot.—BULLER[52] describes the destruction of pine paving blocks in Birmingham, England, by *Lentinus lepideus* Fr. This fungus produces a dry rot which in its microscopic and chemical aspects resembles the destruction of wood by *Merulius lachrymans*. Cellulose is removed from the walls and hadromal is left behind. The ravages of the fungus were somewhat checked by a dipping in creosote which the blocks had received before being laid down.—H. HASSELBRING.

Self-digestion of endosperm.—POND summarizes[53] the literature on this point, and finds no clear proof that the amylaceous endosperm of grasses or the horny endosperm of palms is capable of self-digestion, though this has been claimed by authors and the claim has been accepted hitherto. He himself carefully tested this point in the seed of the date, *Phoenix dactylifera*, and finds its endosperm incapable of self-digestion.—C. R. B.

Formation of chlorophyll.—According to PALLADIN this is a process of oxidation, dependent upon the presence of sugar solutions of low concentration (10%); but ISSATCHENKO reports[54] that chlorophyll formation depends only on the energy of light, occurs in conditions deemed unfavorable by PALLADIN, and is not inhibited by concentrations of even 30–50 per cent. sugar in detached leaves of *Vicia Faba*.—C. R. B.

Caprification.—LONGO has been investigating the fig and caprifig, and in advance of the full memoir with illustrations has published a brief preliminary announcement.[55] As the differences from previous accounts are those of detail rather than fundamental in character, a review will be deferred until the appearance of the full paper.—J. M. C.

Anatomy of Epigaea.—The histology of the stem and leaf are described in a paper by ANDREWS.[56] The most noteworthy point is the occurrence of glandular hairs on the lateral branches, and the suggestion is made that these aid in absorption of food.—M. A. CHRYSLER.

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[52] BULLER, A. H. REGINALD, The destruction of wooden paving blocks by the fungus *Lentinus lepideus* Fr. Jour. Economic Biol. 1:1–12. *pls 1–2*. 1905.

[53] POND, R. H., The incapacity of the date endosperm for self-digestion. Annals of Bot. 20:61–78. 1906.

[54] ISSATCHENKO, B., Sur les conditions de la formation de chlorophylle. Résumé. Bull. Jard. Imp. Bot. St. Petersb. 6:27. 1906.

[55] LONGO, B., Ricerche sul fico e sul caprifico. Rend. Accad. Lincei 15:373–377. 1906.

[56] ANDREWS, F. M., Die Anatomie von *Epigaea repens* L. Beih. Bot. Cent. 19: 314–320 *pls. 6–8*. 1905.

NEWS.

Dr. W. W. Rowlee, Cornell University, has been advanced to a full professorship of botany.

Dr. C. F. Hegelmaier, professor of botany at the University of Tübingen, has died at the age of 72 years.

Professor L. M. Underwood, Columbia University, has received the degree of doctor of laws from Syracuse University.

Dr. Franz Buchenau, the well-known monographer of Junaceae, died at Bremen, April 23, at the age of seventy-five years.

The German Botanical Society has offered a prize of 1000 marks for a monograph on polymorphism in the algae.—Science.

Dr. D. T. MacDougal has been elected a foreign member of Hollandsche Matschappij van Wetenschappen, the Dutch Academy of Sciences.

Professor Bruce Fink, the lichenologist, of Iowa College, has resigned to accept a professorship of biology in Miami University, Oxford, Ohio.

Dr. Friedrich Czapek, of Prague, has been appointed professor of botany and director of the botanic garden and institute of the University of Czernowitz.

Professor George Macloskie, Princeton University, has retired from active service, having been appointed Professor Emeritus. He has been in charge of the botany of that institution since 1875.

Botanical appointments confirmed recently by the trustees of the Ohio State University are as follows: Robert F. Griggs, assistant professor; Freda Detmers, instructor; and L. A. Hawkins, fellow.

Professor Conway MacMillan has resigned the professorship of botany at the University of Minnesota and will devote his attention to business. The position is to be filled by promotion from the present staff.

Professor D. H. Scott's presidential address before the Royal Microscopical Society, entitled "Life and Work of Bernard Renault," is published in Jour. Roy. Micr. Soc. **1906**: 129–145, with an excellent portrait.

Howard S. Reed, instructor in botany at the University of Missouri, has resigned his position to accept an appointment in the Bureau of Soils, United States Department of Agriculture. H. L. Shantz has been appointed to succeed him.

THE EIGHTH annual session of the biological station of the University of Montana will be held at Flathead Lake from July 11 to August 16. This station combines the advantages of lake, plain, and mountain. Botany is in charge of THOMAS A. BONSER, of the Spokane high school.

HIS ASSOCIATES on the faculty of Brown University lately presented to Professor W. WHITMAN BAILEY a loving-cup, in token of their esteem for him personally and in commemoration of his twenty-nine years of active service, from which he retires this year. At a meeting of the trustees at Commencement he was appointed Professor Emeritus.

MRS. J. H. SCHAFFNER, of Columbus, Ohio, died recently after a brief illness. This is not only a sad loss of a devoted companion to Professor SCHAFFNER, but a botanist of promise and ability has passed away. Mrs. SCHAFFNER had published little, perhaps only one paper, over her own name, but a piece of completed cytological work will soon appear as a posthumous paper.

IN THE *Generalversammlungs-Heft* closing volume 23 of *Ber. Deutsch. Bot. Gesells.*, the following biographical sketches are published: WILHELM SCHWACKE, by TH. LOESENER; EDUARD TANGL, by G. HABERLANDT; JOHANN ANTON SCHMIDT, by E. PFITZER; OTTO WÜNSCHE, by J. ABROMEIT; FEDERICO DELPINO, by O. PENZIG; LÉO ERRERA (with portrait), by E. DE WILDEMAN.

AT THE REQUEST of some members of the American Medical Association Dr. HERMANN VON SCHRENK made a pathological exhibit at the recent meeting of this association in Boston. The exhibit showed types of some diseases of plants and some of the conditions producing these diseases. The manner of infection and spread of disease, the symptoms and causes, the methods of treatment and of investigation were illustrated. The time for securing the material was extremely limited, but nevertheless the exhibit occasioned much surprise to the medical men, though it showed but partially the work which plant pathologists have accomplished.

ERRATUM.—The date of publication of the June number was incorrectly given in the table of contents for the month, and in the list of dates of publication accompanying the title pages of the volume. On p. vi, line 23, for June 30 read July 7.

VOLUME XLII NUMBER 2

BOTANICAL GAZETTE

AUGUST, 1906

THE NASCENT FOREST OF THE MISCOU BEACH PLAIN.

CONTRIBUTIONS TO THE ECOLOGICAL PLANT GEOGRAPHY OF THE PROVINCE OF NEW BRUNSWICK, NO. 4.[1]

W. F. GANONG.

(WITH FOURTEEN FIGURES)

THE extreme northeastern angle of the Province of New Brunswick, as the accompanying map will show, is formed by the island of Miscou. The northwestern margin of this island is an extensive sandy beach plain, growing rapidly by action of the sea, locally called Grande Plaine. On this plain there is developing a forest which exhibits every stage of formation from the salt plants of the open sea beach to the heterogeneous vegetation of the mixed woods. The conditions are unusual and the phenomena of proportional interest. In August 1905 I was able to give the place some two weeks of observational study, with results which follow.

In all such studies as this the correct identification of the plants is of first importance, and identification is becoming a matter of such difficulty that only a professional systematist is competent authority. Accordingly I have sent all of my collections, including a specimen of every plant I found at Grande Plaine, to Professor M. L. FERNALD, of the Gray Herbarium of Harvard University, who has been so kind as to determine their identity, and, as well, to give me the names they should bear in accordance with the recommendations of the Vienna Congress. I wish here to express my indebtedness to him and my best thanks for this invaluable aid. Such is the origin of the nomenclature of this paper.

[1] No. 3 is in the BOT. GAZETTE 36:161–186, 280–302, 349–367, 429–455. 1903.

As to previous literature of this particular subject, there is none. In 1886 Dr. G. U. HAY made a collection of Miscou plants for the Geological Survey of Canada, but no account of them was ever published, and no other botanist has heretofore been on the island. In many respects, however, as the reader will observe, the vegetation of this beach plain resembles closely the vegetation

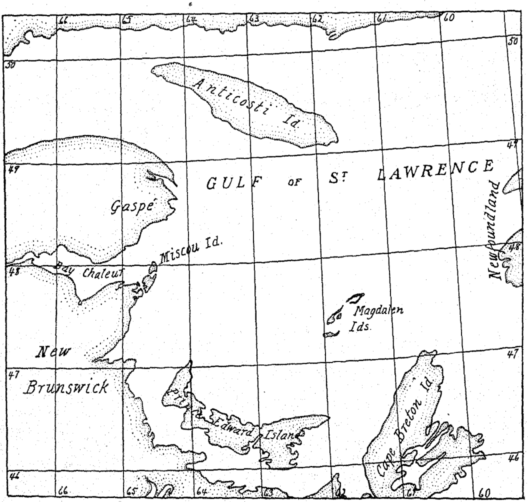

FIG. 1.—Outline map of part of the Gulf of St. Lawrence, to show the geographical position of Miscou Island.

of the sand beaches and dunes of Lake Michigan as described in COWLES's well-known memoir,[2] and many of the conclusions of that work are also applicable here.

Grande Plaine extends along the west side of Miscou. Beginning on the south at Eel Brook (see the accompanying map, *fig. 2*),

[2] BOT. GAZETTE 27:95–117, 167–202, 281–308, 361–391. 1899.

where it is but a few yards wide, it rapidly broadens northward until it reaches some half a mile across, and then narrows again towards its northern end, which is also the northernmost point of the island. Though nearly level as a whole, it is by no means flat, for it is composed of a series of approximately concentric dune beaches, which, two or three in number at Eel Brook, increase to over forty opposite Lac Frye. In height these dune beaches vary from two to five or six or even seven feet (0.6–2^{m}) and in breadth from eight or ten up to forty or fifty paces. At its widest part, which comprises some thirty or more of the beaches, new ones are plainly being rapidly added, while at its northern end the entire plain is being washed away by the sea, which is cutting sharply across the ends of the old beaches. About two-fifths of the plain, including the older parts next the upland, are forested; about two-fifths, including all the outer and newer parts, are open, clothed only by the waving beach grass; the intermediate zone, a small one-fifth of the area of the plain, is a

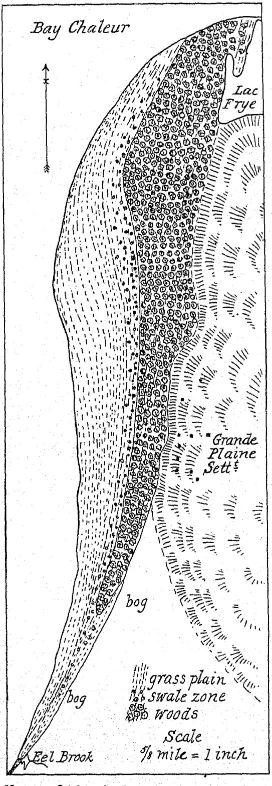

FIG. 2.—Map of Grande Plaine, Miscou Island; from an amateur survey by the author; dotted boundaries are only approximate; the heavier dotted line outside the swales represents approximately a line of higher dune beaches.

transition zone where the forest is pushing its advance into the open ground. The mode of formation of this remarkable plain, involving the anomaly of extensive land-building on a sinking coast, I have described somewhat fully elsewhere.[3] Briefly, the facts are these. As the result of peculiarities of the topography, wind, and tides of this region, there is formed on the shallow northwestern side of Miscou a kind of great eddy in which all movable materials, sand and gravel from the wear of the rapidly crumbling adjacent coasts, as well as driftwood, waterweeds, and other flotsam, often from a great distance, tend to collect, and thence are driven ashore by the prevailing westerly winds. Formerly the island extended farther north than now, carrying with it both eddy and plain; but the general subsidence actively in progress in this region has carried its low northerly end beneath the sea, thus forcing the eddy and the accompanying plain-building gradually southward. The northern end of Grande Plaine today is being rapidly washed away (compare map), to be redeposited farther south, and the plain as a whole is thus rolling by its outer margin southward along the coast. The subsidence of the land has produced another effect upon the plain, and one of considerable consequence to its vegetation, namely, its inner and older part averages somewhat lower, that is, less above sea-level, than the outer and newer part, thus leading to a settling of water towards the older inner parts, and a relatively higher water-table in them. That we have here a beach plain, instead of a series of lofty sand dunes, is the result of the fact, apparently, that the dry sand of the beach is blown ashore no faster than the beach grass can fix it. At both the northern and southern ends of the plain, however, there is some approach to a building of true, though low, dunes.

My brief study of the vegetation of Grande Plaine was entirely observational, not at all instrumental, nor do any meteorological or other exact physical data for this region exist. Grande Plaine lies at sea-level in latitude 48°, beside a shallow sea, warm in summer but frozen over in winter. The summer climate is remarkably equable, of a temperature most comfortable for man, with no fogs and but little cloudy weather. The rainfall must be not far from

[3] Bull. Nat. Hist. Soc. N. B. No. 24:453. 1906.

45 inches. Heavy winds from the west prevail in summer. The soil is of pure quartz sand derived from the wear of the gray carboniferous sandstones of the region, this sand having, of course, the usual relations to water-supply, mineral nutrients, etc. No other special factors with a bearing upon the vegetation appear to be prominent.

We turn now to consider the vegetation. Although it presents every gradation from humble herbs of the open beach to the densest woods, nevertheless the eye becomes accustomed to recognize, and the speech to designate, certain definite vegetational regions. These represent the modes or climaxes, as it were, in the vegetation curve —the parts which exhibit a distinctive character in the physiognomy of the whole. They are the following: (1) the new beach, (2) the grass plain, (3) the swales, (4) the sandy woods, (5) the closed woods.

THE NEW BEACH.

The characteristic open, or new, beach of Grande Plaine, the kind which best illustrates the mode of growth of the plain, is to be found opposite its middle and broadest part; for towards the northern and southern ends its structure is modified by local conditions of erosion and dune-building. Outside of all is a broad sloping inter-tidal beach of pure sand without vegetation (*fig. 3*). Above it is the narrow band between ordinary and extreme high tides, from which the drying sand is being driven landward by the winds; it is also vegetationless, or with but stragglers from the upper beach. Finally, there is that broad shelf, very well shown in the accompanying photograph (*fig. 4*), reached only by the very highest tides, composed of fine quartz sand, intermixed with some gravel and occasional flat cobbles; it is covered with scattered driftwood among and over which the dry sand is being forever driven, shifted, and piled. Thus the new beach offers a barren habitat to plants, for it has a mineral-poor soil, drenched often by salt, forever shifting, and exposed to the unbroken force of frequent heavy winds. The vegetation is plainly responsive to these conditions. It is extremely scanty, the plants growing widely isolated, while many square yards do not show any vegetation at all. Thus competition among the plants seems not to exist, and the struggle is wholly with the

physical environment. The most characteristic plant by far is the small, radiate-decumbent, succulent, annual saltwort, *Salsola*

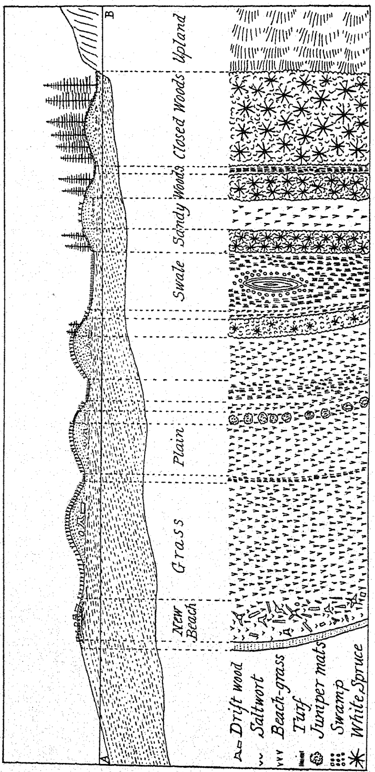

FIG. 3.—Idealized section and map to show the mode of formation of the beach plain, and the distribution of its vegetation; the line *AB* is true level, and may be taken to represent approximately the position of the water-table.

Kali, which occurs but rarely and for the most part in the lee of

some shelter, such as a hollow or large piece of driftwood. Next in abundance, though but scarce, is the little fleshy, rosette-like, annual sea rocket, *Cakile edentula* (*C. americana*). Third in abundance is the low halo-rosette, perennial sea lungwort, *Mertensia maritima*, here seemingly growing as an annual, also mostly in places of some shelter. Rarely, and then only in a sheltered position, occur tiny radiate-creeping plants of the beach pea, *Lathyrus maritimus*, growing apparently only as an annual, and sometimes showing a marked difference in the windward-creeping and leeward-

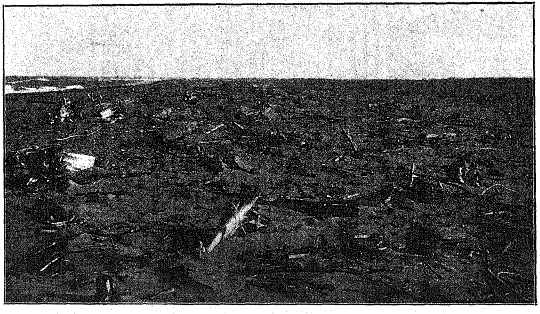

FIG. 4.—Typical open, or new, beach, looking north; among the driftwood occur scattered tufts of saltwort and beach grass.

creeping shoots on the same plant, the former being much shorter and smaller-leaved. Even rarer is the radiate-creeping, small-leaved, halo-scurfy annual, *Atriplex patula hastata.* Here and there, however, especially in sheltered places, arise the tufted culms of the beach grass, *Ammophila arenaria*, the characteristic sand-binding perennial of the dune beaches next to be considered, here seemingly growing from seed. I was able to find no other plants on the new beach. Thus we see that this vegetation is distinctly adjusted to the physical conditions, for it is of great paucity, of small and slow growth, annually renewed, closely ground-appressed, and strongly xerophytic.

THE GRASS PLAIN.

Inside the line of open beach begins the sand plain, composed of a great number of approximately parallel dune beaches, forming smoothly swelling ridges and hollows of elevations and breadths already described. Every dune beach, I believe, originates with a core of driftwood. As the tidal beach is built outwards by the addition of sand, driftwood continues to collect on its uppermost part, until finally some unusual combination of great winds with high tides sweeps it up beyond reach of further disturbance. Then the driving sand from the beach is caught among it; the beach grass gains a foothold in the sheltered places, spreads, and checks the further movement of this sand. Then more sand is driven shoreward, and it grows into a low dune which is fixed by the beach grass as fast as it rises. The limit is reached only when a new line of driftwood has been formed outside and begins to stop the sand for its own growth. The resultant dune beach offers severe conditions for plant life, for its surface is swept, especially on the summit and windward slope, by heavy winds; it is heated intensely by the sun; it is readily movable; and it forms a soil extremely poor in mineral nutrients.[4] It lacks the salt of the newer beaches, however, for this is soon removed by the rain; and it possesses an ample supply of moisture a foot or two beneath the surface, for the supply brought by the rain drains but slowly away, owing to the low gradient of the water-table. These conditions, especially at their extreme on the summits and windward slopes of the beach dunes, are endured by practically but a single plant—the herbaceous-perennial, subterranean-creeping, xero-culmed, deep-rooting beach grass, *Ammophila arenaria*, which occurs, without any competitor whatever, in open scattered tussocks, only partially covering the ground, as well shown in *fig. 5*, and in closer view in *figs. 6* and *7*. It happens that this grass is of considerable economic value to the neighboring farmers, who cut it and haul it for hay, and whose cattle graze upon it; its destruction in this way causes an irregular exposure of the outer beaches, permitting them to be irregularly cut by the wind. It is for this reason, I have no doubt, the newer outer beaches

[4] As indicated by KEARNEY'S recent studies: BOT. GAZETTE 37:426–436. 1904.

are so much more irregular in their various characters than the older inner beaches, which antedate the advent of man.

But while the beach grass has no competitor, it affords a shelter, especially behind its tussocks, permitting the growth of a number of other plants, which, however, form but an insignificant part of the entire vegetation, and which are widely separated from one another. Most important of these, perhaps, is the beach sedge *Carex silicea*, which grows in scattered tussocks here and there among the beach grass, and it is indeed the only other plant which

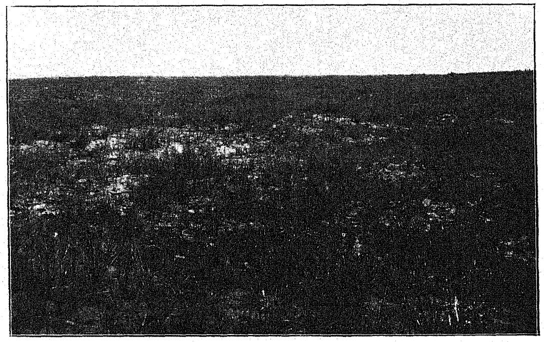

FIG. 5.—Typical grass plain, looking north; practically no plant visible except the beach grass.

seems at home in this situation. The remainder of the plants, all sparsely or rarely represented, are obviously stragglers from the most diverse habitats, many of them quite unexpected residents in such a situation. Thus, dwarfed saltwort strays in from the beach, and the beach pea is here somewhat more flourishing than on the open beach. Then there are greatly dwarfed individuals of certain ubiquitous forms able to endure a wide range of physical conditions, such as the dandelion, *Taraxacum officinale*, which extends in sheltered spots even to the outer margin of the plain; the Canada thistle, *Cnicus arvensis;* the sow thistle, *Sonchus arvensis;* the

field sorrel, *Rumex Acetosella*, in dwarfed-rosette, very red forms; the evening primrose, *Oenothera biennis;* and the moonwort, *Botrychium ternatum intermedium.* There are also some forms usually characteristic of rather a dry habitat, such as the pearly everlasting, *Anaphalis margaritacea*, and a western yarrow, *Achillea lanulosa.* In addition there are others, generally in more sheltered spots and also greatly dwarfed, which usually prefer a moister habitat, such as the two western roses, *Rosa acicularis* (*R. Sayi, R. Engelmanni*) and *Rosa lucida;* a western violet, *Viola adunca;* a stitchwort, *Stellaria longipes laeta;* a silver weed, *Potentilla Anserina concolor;* the stellate false Solomon's seal, *Smilacina stellata;* and one of the vetches, *Vicia Cracca.*[5] The great diversity of natural habit of these plants, their scanty and irregular occurrence, and their dwarfed size and rosette-forming tendency all unite to show that none of them are here at home. Obviously they are the ones which, of all the many kinds which must be brought to this plain by natural modes of dissemination, are sufficiently tolerant physiologically to be able to germinate under, and then to withstand, these extreme physical conditions, eking out here a starved and precarious existence. The conditions for germination upon the sand must be extremely severe, and it is very likely that other kinds of plants could exist here as adults, could their seeds develop; and further it is probable that the individuals which do exist on the plain are those whose seeds happened to fall in especially favorable spots, or became properly buried by the moving sand. Else why are they so few? The universal dwarfing is due in all likelihood not to the heat and dryness of the surface, nor to any salt content in the soil, and certainly not to a scarcity of soil water, but to the paucity of mineral nutrients in the sand. This is in harmony with another feature they mostly show in common—very deep and, I think, much-branching roots. The fact that they come

[5] The following Grande Plaine plants appear to be new to the flora of New Brunswick: *Achillea lanulosa, Viola adunca, Rosa acicularis, Stellaria longipes laeta*, and *Potentilla Anserina concolor.* Certain others are new in name, the species having been recently more exactly defined and segregated: *Alnus mollis, Myrica carolinensis, Vaccinium Vitis-Idaea minor.* Others are new in name because made to conform to the rules of the Vienna Congress, but in these cases the names of Gray's *Manual*, 6th edition, have been given in brackets.

from such a diversity of natural habitats, and yet live in this peculiar situation upon an equal footing, shows how far we are from understanding the real bases of physiological adaptation, and further shows that in the study of the physiological life-histories of plants lies the most important and attractive field for the ecologist of the near future.

So much for the exposed parts of the dune beaches. But in addition they offer, upon their inner or leeward slopes and in the hollows, situations more sheltered, not so much from the sun, since

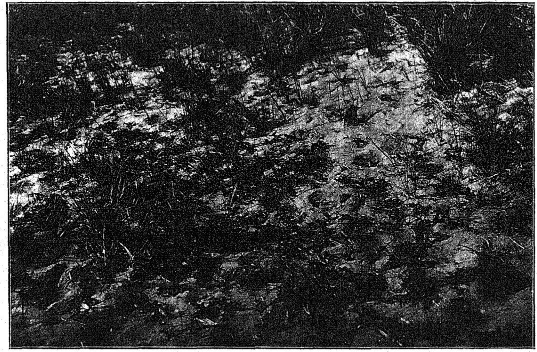

FIG. 6.—Typical hollow between outer dune beaches; the tall grass is all beach grass, but the small plants among it are the common strawberry.

their average course is nearly north and south, but from the westerly winds. The older inner dune beaches also are protected to some extent by the newer outer ones, as well as by their slightly lower average level. The difference between leeward slope and hollow is not simply one of degree of shelter, however, but also of physical conditions, for the hollow is much nearer the source of water supply, the free table of which is not over a foot or two beneath the surface. In consequence of these differences we can recognize three distinct phases of vegetation: *first*, a larger development on the leeward

slopes of plants which are small and rare on the outer slopes; *second*, a distinctive vegetation of the hollows; and, *third*, a distinctive vegetation of the inner slopes.

As to the first phase, it is enough to note that several plants, in particular the pearly everlasting and the wild roses, small, scarce, and scattered on the outer slopes, become larger, frequent, and even patch-forming on the inner; and this is true also in less degree of other species. The beach grass persists in all situations.

The second phase is the vegetation of the hollows. The very first plant to appear in this situation, and that too near the outer beaches, is always, strangely enough, the common wild strawberry, *Fragaria virginiana*, apparently of normal size and form, seemingly quite at home, and spreading abundantly by runners, so that it forms considerable patches. The appearance of the nascent patches is well shown in *fig. 6*. As soon as the patches reach an appreciable density, such that they afford a cover to the ground, then turf-forming grasses, of which the first is the red fescue, *Festuca rubra*, appear and initiate the turf-formation which is so important a feature of the swales to be described below. The strawberry, of course, is one of the most tolerant, and hence ubiquitous, herbs of our flora, and its situation here is partially explained by the nearness of the abundant water supply. Yet it is surprising to find it taking so important a part in a vegetation in so peculiar a position.

The third phase of this vegetation is that characteristic of the sheltered slopes. First of such plants to appear, and the most common and characteristic, is the dwarf creeping juniper, *Juniperus Sabina procumbens*, of which single plants originate just below the beach dune crests, and creep radiating, more to leeward than to windward, in a close dense mat covering many square feet. A young plant is shown in *fig. 7*, in characteristic form and position. On the inner beaches these plants occur upon the outer as well as the inner slopes, and the shelter of the mats thus formed affords in reality the principal starting-point for the development of other plants which lead gradually to the development of the forest, as will be noted under the transition vegetation. In a similar situation, but independently, arise patches of two other characteristic plants, a bright-green, leathery-leaved, tufted shrub, the wax berry,

Myrica carolinensis, which comes to form dense discoid (sometimes almost fairy-ring like) masses on the crests and inner slopes; and the less frequent, low, dense-tufted, white-hairy shrub, *Hudsonia tomentosa*, in irregular close patches. All of these plants are pronounced xerophytes, which amply explains their ability to live in this situation, and even their preference for the somewhat drier upper slopes of the dune beaches. Their xerophilism, in common with that of many other evergreen sand plants, is, as I guess it, an

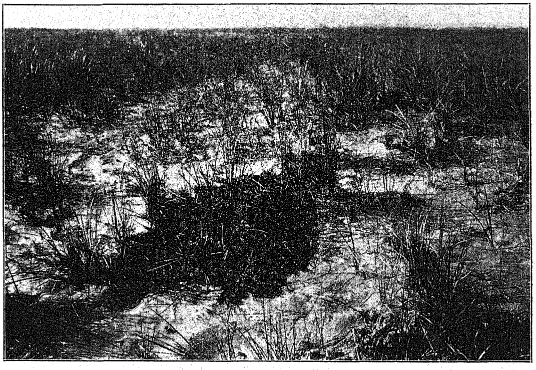

FIG. 7.—Typical upper inner slope of a dune beach; the grass is beach grass, but in the center is a typical plant of dwarf creeping juniper.

adaptation to the physiological dryness which results when, as must often be the case in spring and fall, the ground water is of low temperature and hence slowly absorbed, while the leaves are exposed to high transpiration conditions from the bright sun, heat reflected from the sand, and high winds.[6] The juniper, while perfectly at home here, apparently is so only through coincidence, for its original habitat is seemingly dry rocky hills. But the other

[6] This principle, which from its discoverers we may call the KIHLMAN-GOEBEL principle, seems to me deserving of much more recognition than our students are inclined to give it. At least it calls for careful experimental investigation.

two, the waxberry and the Hudsonia, are characteristic of just this situation, in and to which they have apparently been adaptively developed. Towards the inner dune beaches another low shrub comes in on the slopes, though dwarfed and not abundant, the common blueberry, *Vaccinium pennsylvanicum;* it is evidently not here at home, but its somewhat xerophytic habit permits it to exist. As these various plants grow older and extend their patches, they run together more or less, sometimes two, sometimes three, and even all four. Later others are added to them, initiating the juniper mats and the woods carpet, later to be considered.

The contrast between the vegetation of the outer and the sheltered slopes of the dune beaches comes out with striking clearness a few hundred yards north of Eel Brook, where it happens the entire plain is very narrow, and slopes in both directions from a central higher crest. Outside of this can be seen only the beach grass and its accompanying forms as listed above, while inside the various xerophytic shrubs show to great perfection.

THE SWALES.

Between the open grass plain and the woods occurs a transition zone marked not only by an intermediate vegetation but also by distinctive physical features as well. First of all it is characterized by the presence of several great turf-carpeted and tree-bordered swales, morphologically hollows between the dune beaches which here spread much farther apart than usual. They are well shown in *figs. 8, 10, 11.* They are best developed in the widest part of the plain, hardly occurring towards its southern or northern ends, and outside of them runs a line of higher dune beaches, which indeed can be traced through most or all the length of the plain (*fig. 2*). The swales are narrow southward, but broaden northward, deepening as they go, until in some cases they dip beneath the water-table (thus exhibiting pools), after which they rapidly narrow and rise to disappear northward. Again, the trees of this zone, occurring always along the slopes of the dune beaches, do not exhibit a transition of size and age to those of the sandy woods, but are always so much smaller and younger as to be sharply marked off from them, the case shown in *fig. 10* being very exceptional, and that of *fig. 8*

more typical. Again, the transition from the broad swales to the beaches of the sandy woods is most abrupt, for the latter are regular, narrow, close together with scarcely any hollows between, and also exhibit a curious barrenness on their summits in marked contrast to the better-clothed summits farther out (compare *figs. 8* and *13*). Unfortunately the full importance of these features did not strike me in time for a study of them on the ground, but such data as I possess in notes and maps lead me to believe that the swales are much newer in origin than the beaches immediately inside them, and that they mark the transition from an older series of beaches which formed part of the original Grande Plaine extending far to

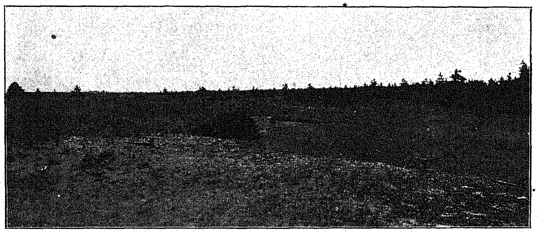

FIG. 8.—Typical transition zone, looking north; showing a swale on the right, with its sharp line of transition to the woods; the trees are all white spruce.

the north of the present island, and a newer series formed by the rolling of the plain down the coast, as described earlier in this paper. All the facts I possess both as to geography and vegetation are consistent with this view.[7]

Aside from the question of age, the swale zone differs physically from the grass plain by its greater shelter from the west winds, its lower level and greater nearness to the water-table, a probable increase of mineral nutrients derived from decaying driftwood and diffusion from the upland, and some slight accumulation of humus.

[7] And it is sustained by the tradition of the residents who say that the plain has been built out from the edge of the woods almost within the memory of men still living. I have discussed the subject more fully in Bull. Nat. Hist. Soc. N. B. No. 24:456. 1906.

The vegetation consists broadly of a higher development of the vegetation of the inner grass plain—the scanty turf of the hollows becoming the broad expanse of meadow turf of the swales, and the juniper mats extending greatly with the addition of many young white spruces. So distinct are the turf of the swales and the juniper mats, with their trees, from one another, that there result glades and vistas of park-like and charming aspect, as shown especially well in *fig. 8*.

First in importance are the juniper mats, for they inaugurate the woods. These mats, composed either of large radiating patches of this plant, or else variously united and combined with patches of waxberry, Hudsonia, and blueberry, extend greatly in diameter, covering the crests as well as the slopes of the dune beaches, and thus form a woody net in the shelter of which several other forms, mostly markedly dwarfed, gain foothold. A typical example is shown in *fig. 9*. Some of the plants of the grass plain persist, especially the beach grass, pearly everlasting, and yarrow. The new forms which appear are, first of all, the common crowberry, *Empetrum nigrum*, and the rock cranberry, *Vaccinium Vitis-Idaea minor*, followed closely by the three-toothed cinquefoil, *Potentilla tridentata*, all of them plants characteristic of dry upland rocky situations. Less frequent are the little gentian, *Gentiana Amarella acuta*, and the large cranberry, *Vaccinium macrocarpon*, plants belonging to moist places. And when the mats are especially well developed there come in, as shown in *fig. 9*, the reindeer lichen, *Cladonia rangifera*, and a brown moss which I take to be the *Aulacomnium palustre* (so much more highly developed in the woods), another curious mixture of xerophytic and hydrophytic forms. We have therefore upon these juniper mats a very heterogeneous assemblage of forms drawn from diverse natural habitats all the way from rocky hills to bogs. They do not exist here, therefore, in virtue of adaptation to this position, but plainly represent those forms of the flora of this region whose adaptations happen to fit these conditions, or whose range of physiological toleration happens to be great enough to permit endurance of the conditions here. Of these matters we shall know more in the future, but their mention helps to emphasize how large an element of accident or incident

there is in adaptation, and how likely it is that adaptation will ultimately prove to be a matter of the loose and large rather than of the exact and minute.

Finally, it is in this same situation, upon the upper slopes of the dune beaches, and usually, but not always, on the juniper mats, that the characteristic trees of the zone, the white spruce, *Picea alba*, develop. Standing in open formation, they do not interfere with one another's growth, and in consequence become,

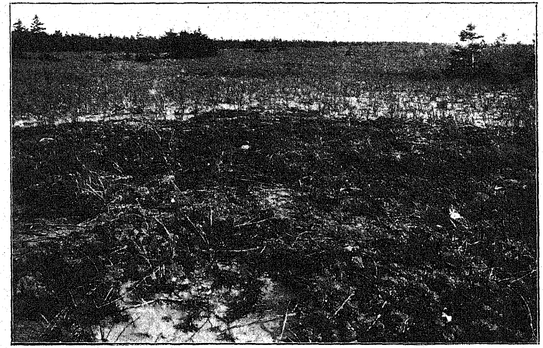

FIG. 9.—Typical large juniper mat on a slope and crest of a dune beach, with a number of associated plants noted in the text; looking south.

except for wind effects, symmetrical in outline and clothed to the ground. They occupy that situation no doubt for the same reason that the shrubs do, as a compromise between the greater wetness of the hollows and the greater dryness of the beach summits. This habit of growing thus upon the slopes, and not on summits or hollows, has a most important effect upon the physiognomy of the vegetation in this zone; for to it is due the openness of the swales, with their regular borders of trees, and as well the openness of the beach summits in the sandy woods later to be noticed. Toward the sea the spruces are small and dense, and often show, as in *fig. 11*,

pronounced wind effects. In places many seedling trees may be found, though the distribution of these is curiously irregular. In one place only did I find any other tree, and that was a single specimen of the prince's pine, *Pinus Banksiana*.

If it be asked why the white spruce is the first tree to develop on these plains instead of some other of those growing on the upland near by, I can only say that an answer must wait until we know something about the physiology of the white spruce and of other trees of the vicinity.

We turn next to the swales, those long open hollows carpeted by a close turf, and bordered by spruces. The general appearance

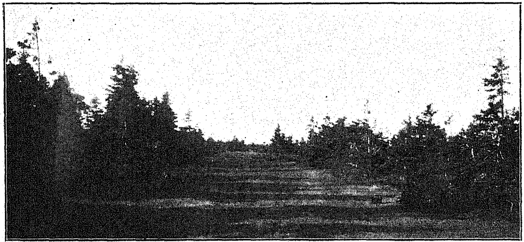

FIG. 10.—Highly developed swale, looking south; on the left is the edge of the sandy woods with old trees, and on the right a line of much younger trees, here much larger than usual.

of the turf is well shown on the right in *fig. 8*, and extremely well in *fig. 10*, which shows perhaps the best-developed of all the swales. The turf is a good deal modified in vegetation by the grazing of cattle and horses, yet its general characters show plainly enough. Originating in the outer hollows with the strawberry, as already noted, the real turf begins with the red fescue grass, *Festuca rubra* (*F. ovina rubra*), which soon drives out the strawberry. To this, as it becomes compact in the inner hollows, other grasses are rapidly added, especially the June grass, *Poa pratensis*, and then the brown top, *Agrostis alba*. After these comes a rush, *Juncus Vaseyi*, and the little sedge, *Carex Oederi*. Very likely, also, there are other

grasses which, owing to my imperfect knowledge of those groups, I overlooked. On and among these plants occur others, among which I have collected the following: the eyebright, *Euphrasia americana* (*E. officinalis*); the bugle weed, *Lycopus uniflorus* (*L. virginianus*); a tiny everlasting, *Antennaria neodioica;* a pearlwort, *Sagina procumbens;* the plantain, *Plantago major;* the two common cinquefoils, *Potentilla norvegica* and *Anserina;* the fall dandelion, *Leontodon autumnale;* and the white clover, *Trifolium repens.* These forms, in common with the grasses, are all greatly dwarfed

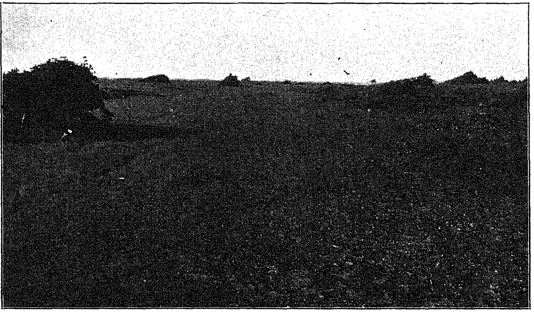

FIG. 11.—An outer swale, looking north; in the center clumps of blue flag; on the slope on the left white spruce and waxberry; on the right is a low depression with a thicket of poplar (the white spruce among it being on a local elevation).

and derived from diverse habitats, and are evidently a collection of heterogeneous stragglers from the neighborhood, held together by no stronger bond than ability to eke out existence in this inhospitable position. The majority belong to somewhat moist places, and they find an ample supply of water; for the water-table even in the driest summer is within a foot of the surface, and of the sweetest water. Evidently it is not dryness which stunts the forms, but most likely, as I believe, paucity of mineral nutrients. The turf represents the first closed formation we have met with, and

competition may therefore determine some of its minor features, but to these I gave no attention.

The turf reaches its climax in the open swales like those shown by *fig. 10*. In the woods it disappears, as will be noted under the next section; but towards the lower levels, especially towards the pools of standing water, it gives way gradually, by definite steps, to an assemblage of true swamp plants. The very first of these to appear in the lower places in the swales is always the common blue flag, *Iris versicolor*, and characteristic scattered clumps of this plant may be seen in the foreground in *fig. 11*, in the distance

FIG. 12.—Marshy swale, looking south; in the center a permanent pool with margin trodden by cattle; behind it are cat-tails and rushes, and back of them a thicket of poplar; on both right and left is sweet gale, and in the foreground is the blue flag.

on the swale in *fig. 8*, and on the left margin of the swale in *fig. 10*. Next follows always the sweet gale, *Myrica Gale*, and after that low bushes of the balsam poplar, *Populus balsamifera*, a plant which forms very dense thickets and grows larger as the situation is more sheltered. Finally the pools of standing water are reached, and on their margin occur cat-tails, rushes, and mare's tail, *Hippuris vulgaris*, with some other forms which I have not attempted especially to study. The plants may be variously combined according to local circumstances, but a very typical arrangement is shown in *fig. 12*. It is plain that we are dealing here simply with an ordinary

swamp, offering nothing peculiar unless it be the small size of some of the plants, notably the poplar. But these places develop yet farther in time, and there come in after the poplar three willows: *Salix balsamifera*, *S. lucida*, and *S. candida*, forming very dense thickets, and apparently under congenial conditions. Finally comes in the alder, which appears to be mostly a form of the green alder, *Alnus mollis*, giving us the culmination of the swale thickets.

THE SANDY WOODS.

Inside the swale zone, through almost the whole length of the plain, extends a narrow zone, only some four or five dune beaches

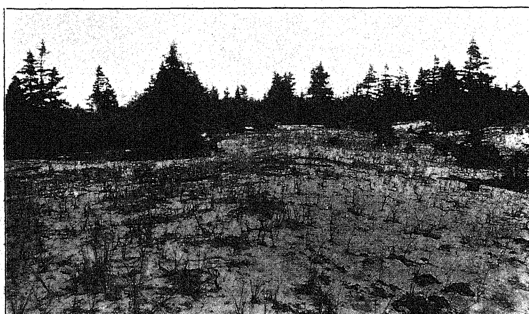

FIG. 13.—Typical sandy woods, just inside the swales, looking north; in the center a dune beach, bearing scanty beach grass and reindeer lichen, while on the slopes are small juniper mats with white spruces.

wide, of remarkable sandy woods, whose characters are well shown by *fig. 13*. Their most striking feature is perhaps the relative bareness of the tops of the beaches, which remain far more clear of vegetation than do most of the beaches outside of them; and this bareness, in conjunction with the presence of trees on the slopes and in the hollows, gives rise to curious vistas as shown by the photograph. The bareness must have some physical basis, but I was not able to discover it. These dune beaches, further, are very narrow, low, and regular, with hardly any true hollows between, so that the turf

from the swales is very scanty, almost wanting, in this zone. Further, the trees, all of them white spruces, are much older than those of the swale zone, the transition being commonly of the most marked abruptness. All of these features tend to emphasize the conclusion earlier given, that there is an abrupt physical difference between the beaches of these woods and those outside, a difference which, I feel sure, is one of age. The position of the zone would indicate that it possesses more favorable physical conditions as to water, mineral supply, and shelter than the zone outside, with which the large size of the trees is in agreement. But the bigness of the trees makes the barrenness of the beaches all the harder to explain. In their vegetation the sandy woods exhibit three divisions: the sparse, scattered beach grass and reindeer lichen (*fig. 13*) on the beach crests already mentioned; a few and small patches of turf which can hardly obtain a foothold where the hollows are so small; and the juniper mats in the slopes and hollows with their well-grown white spruces. The mats, however, are no longer entirely creeping, for the junipers send up numerous erect shoots. With them persist several of the plants from the transition zone, especially the rock cranberry, the three-toothed cinquefoil, the pearly everlasting, and a few others. But in addition new forms come in, especially and characteristically the bearberry, *Arctostaphylos Uva-ursi*, a rocky-hill plant, here creeping radiately over the sand, apparently under congenial conditions. Beneath the shelter of the trees appear some plants of the woods carpet which we may best consider under the next section. The trees themselves are of moderate size, rarely if ever over 20 feet in height.

A fact of interest about the juniper mats, applying also to a less degree to the forest mat which succeeds it in the closed woods, is its very slight hold upon existence on the sand, for where teams cross and disturb it, the entire mat dies and soon disappears. Such instability shows forcibly how hard are the conditions of life in this situation, and how narrow the margin between success and failure.

THE CLOSED WOODS.

The climax of the sand-plain vegetation is reached in the dense though dwarfed mixed woods extending between the sandy woods and the upland. A typical view of the closed woods is shown by *fig. 14*.

Physically the situation is much more protected than the zones outside of it, and, lying at a still lower level, it has a moister soil. The soil, however, is still of sand, though it contains some humus from the decaying vegetation and must derive some mineral matter by diffusion and drainage from the upland. Very likely also the sand is shallower here than farther out (*fig. 2*), and hence some influence of the minerals of the underlying soil may be felt, while in places an appreciable enriching of the soil must result from the decay of

FIG. 14.—Typical closed woods, chiefly of white spruce, but with some deciduous trees in the background; the closed forest carpet shows in the glade of the left foreground.

the bodies of the walrus, formerly slain here in great numbers, as manifest by their semi-fossil bones.[8] These additional sources of mineral nutrients, however, by no means furnish a supply sufficient for the proper growth of the woods, for in every feature they exhibit marked depauperation as compared with the same species on the neighboring upland.

In relation to the preceding zone, the closed woods consist essen-

[8] Described more fully in a note in Bull. Nat. Hist. Soc. N. B. No. 24:462. 1906.

tially of a greater development of the juniper mats, which unite to form a complete unbroken carpet, together with a greater development, both in number and size, of the white spruce trees, to which are added some deciduous trees and shrubs. And where the hollows dip lower than usual, and towards the upland in places, this forest merges to alder and cedar swamp.

We consider first the woods carpet. Morphologically it is a direct development of the juniper mats of the outer zones, though but little juniper, aside from occasional erect shoots, is left. With it persist some of its earlier associates, the rock cranberry, three-leaved cinquefoil, some grasses, the bearberry, and the reindeer lichen, varying in their respective development according to situation. To these are now added dwarf plants of the bunchberry, *Cornus canadensis*, the twin flower, *Linnaea borealis americana*, *Pyrola chlorantha*, the pipsissewa, *Chimaphila umbellata*, and an abundant brown moss, which has been identified for me by Mr. A. J. GROUT as *Aulacomnium palustre*, a typical swamp moss. Upon this carpet develop a few larger forms, especially the abundant wild sarsaparilla, *Aralia nudicaulis*, the gooseberry, *Ribes oxyacanthoides*, the dwarf raspberry, *Rubus triflorus*, with others less conspicuous.

We consider next the trees of these woods. First in importance and size, far surpassing all others in both respects, is the white spruce. It attains a height of perhaps 7.5^{m}, a diameter near the ground of perhaps 45^{cm}, and it exhibits over 100 annual rings, though perhaps some may be much older than those I counted, which were cut by the residents for wood. The next to appear is the balsam fir, *Abies balsamea*, becoming somewhat abundant and characterized by a spruce-like arrangement of its leaves all around the stems. Then follow the red maple, *Acer rubrum*, the aspen, *Populus tremuloides*, the paper birch, *Betula alba papyrifera* (in very small trees however), and the mountain ash, *Pyrus americana;* while the common undershrubs are the red dogwood, *Cornus stolonifera*, and the black alder, *Ilex verticillata*. There are probably scme others, but these I believe are all that are notable.

In especially low places, such as in certain hollows, and at the contact of plain and upland, the conditions verge towards those of

a swamp, and swamp plants appear—the iris, the sweet gale, some mints, species of Galium, and the dewberry; while the spruce gives way to the white cedar, *Thuja occidentalis*, and the alder becomes abundant, forming a dense jungle. But this is of less interest than the vegetation of the outer zones, and hence I gave it little study.

Thus it appears that these woods present no features, size of the plants alone excepted, markedly different from those of woods preponderatingly coniferous in the neighboring upland, and they are evidently tending towards the typical woods of this region—the mixed coniferous-deciduous forest.

We have thus another illustration of that principle so important in physiognomic ecology, that vegetation, no matter under what immediate physical conditions it may be, is always tending towards a climax type, determined primarily by climate.

CONCLUSION.

In this paper I have tried to state the facts about the vegetation of a somewhat remarkable place, adding thereto some ecological comment whose chief value is to illustrate our ignorance of that subject. As I understand it, such descriptions as this aims to be may have three values. First, they can present to all who have interest in such matters a series of pictures, as vivid and realistic as possible, of the vegetation of special places, and they are the more valuable according as they are the more clearly and attractively written and the more aptly illustrated. Second, they should help to supply information, badly needed by all of our manuals, about the natural habitats of the common or important species of plants. Third, they can form storehouses of facts about vegetation upon which the future student can draw as the advance of physiological ecology gradually makes possible an understanding of the principles underlying physiognomic ecology. Such descriptive work can be done to profit by the student whose work is perforce confined to his summer vacations, if he but bring to it time and care enough; but he should be content to describe well and to leave interpretation to the field physiologist yet to come. Speculation cannot of itself advance knowledge, and it can bring a subject into disrepute. It is only, I believe, through field physiology, the study

in field laboratories of fundamental plant-dynamics, that ecological knowledge can really be advanced. And the dynamical problems, as I see them, fall under these heads, in the order of importance: (*a*) physiological life-histories of species, (*b*) physics and chemistry of the soil, (*c*) nature of plant-competition, (*d*) a better correlation of meteorological data with physiological phenomena.

SMITH COLLEGE,
Northampton, Mass.

THE DEVELOPMENT AND ANATOMY OF SARRACENIA PURPUREA.[1]

CONTRIBUTIONS FROM THE BOTANICAL LABORATORY OF THE JOHNS HOPKINS UNIVERSITY. No. 5.

FORREST SHREVE.

(WITH PLATES III–V)

THE work of which the results are here given was undertaken at the suggestion of Dr. D. S. JOHNSON, and has been carried out at the Biological Laboratory of the Johns Hopkins University. I wish here to express my thanks to Dr. JOHNSON for much advice and helpful criticism in connection with this work, and to express to Professor WILLIAM K. BROOKS my appreciation of his interest and encouragement. I also wish to thank my fellow-student Mr. SAMUEL RITTENHOUSE for his kindness in gathering material for me during my absence from Baltimore.

The material worked upon was obtained mainly at Glenburnie, Maryland, near Baltimore. Most of it was fixed in the field; and of several killing reagents tried 1 per cent. chrom-acetic and Carnoy's mixture were the most satisfactory. Preparations mere made by ordinary paraffin method and stained with the Flemming triple stain or with cyanin and erythrosin.

DEVELOPMENT OF THE FLOWER.

The earliest stage observed in the development of the flower was in material gathered August 30. There are then to be seen the primordia of the three bracts, the five sepals, and the five petals, which have apparently arisen in the order named. Lying just within the edges of the petals are the staminal primordia, as yet mere papillae, and within them is a flat surface with slight elevation at the center. A somewhat later stage than the last shows progress in the development of the stamens, which now appear as ten groups of protuberances lying in the position before noted (*fig. 2*). Each

[1] Dissertation submitted to the Board of University Studies of the Johns Hopkins University for the degree of Doctor of Philosophy.

group arises from a base which is distinct from the bases of the adjoining groups, and is made up of the primordia of five to eight stamens. There is no suggestion of a pairing of the groups nor of their falling in two whorls. Upon the central flat surface has arisen the ovary, which at its base is pentagonal in outline, and at its apex is surmounted at the angles of the pentagon by the tips of the carpellary leaves. The outgrowths of the wall of the ovary which are destined to give rise to the placentae are upon the sides of the pentagon, which shows each placenta to be made up of the edges of two carpellary leaves (*figs. 2, 14*).

MICROSPORANGIUM AND MICROSPORE.

The staminal primordia early show differentiation into parts destined to give rise to filament and anther. The latter portion bears approximately the same outline in cross section as do the mature anthers. The location of the archesporium is indicated at first only by the slightly greater size of the nuclei in the region of the four microsporangia (*fig. 4*), but soon comes to be more sharply defined by the concentric arrangement of cells in the region of the future parietal cells. The archesporium is at this earliest recognizable stage about six cells in cross section, but grows rapidly to about twelve cells in diameter (*fig. 5*). Development proceeds in the autumn to the differentiation of the endothecium, the two or three parietal layers, and the pollen mother cells. There is yet no distinction of definitive sporogenous cells and tapetum. In this condition the stamens pass the winter.

The elongated parietal cells do not contribute to the tapetum, but it is made up entirely from the isodiametric cells of the archesporium. The outer outline of the tapetal layer is continuous, and the inner is irregular only to an extent which makes it in some places two cells in thickness and in other places three. The cells of the tapetum do not wander among the definitive sporogenous cells Shortly after the differentiation of the tapetum, and before the pollen mother cells are in the synapsis stage, the tapetal nuclei divide once by mitosis, and so far as observed once only. At the time of tetrad division the tapetal nuclei are enlarged, the chromatin is granular and scattered, and the nucleoli are large. At the time of the forma-

tion of the walls of the pollen grain the cytoplasm of the tapetal cells becomes much vacuolated and the nuclei lose their chromatin; but at no time does the layer become broken. The parietal layers at the time of the tetrad division are three to five in number, the endothecium is thickened on its inner and lateral walls, and the epidermis is undifferentiated. The thickening of the endothecium walls takes places very late—simultaneously with the division of the pollen grain nucleus—the cells for some time previous to this being filled with starch.

Dehiscence is by means of two longitudinal slits, each of which opens two pollen sacs of the anther. A deep crease runs between each pair of pollen sacs upon the two sides of the anther, penetrating to the point at which the two microsporangia lie nearest each other (*fig. 13*). At this point is a group of small cells reaching from one microsporangium to the other, the walls of which are thrown into creases and folds, and fail to thicken in the further development of the anther, as do the neighboring cells.

The pollen mother cells apparently lie in the synapsis stage for several days. At their first division it is possible to count the chromosomes, the reduced number being twelve and their form short and blunt (*fig. 8*).

The tetrad division is simultaneous, there being no formation of wall after the first division. After a short period of adherence in tetrads the pollen grains round off and acquire the coats. The mature pollen grain is marked with eight meridional grooves so as to resemble a muskmelon. Beneath the grooves the intine is several times thicker than between the grooves (*fig. 11*). While the pollen grain is yet within the anther the nuclear division takes place which gives rise to tube and generative nuclei (*fig. 12*). In this condition the grains are shed, the stamens nearest the ovary opening first, and the outer ones successively.

OVULE AND MEGASPORE.

The placental outgrowths which arise from the flat sides of the ovary, at the point of juncture of the edges of the carpellary leaves, grow inward almost to the center of the ovary, and these I shall designate as the "main placental outgrowths" (*fig. 14*). Each

main placental outgrowth sends out two lateral outgrowths so as to resemble in cross section a letter T, in which the arms have been bent downward. Each pair of adjoining lateral outgrowths is closely appressed and directed backward toward the angles of the ovary. In the lower part of the ovary the adjacent lateral outgrowths fuse, but do not extend to the bottom, and in the upper part they do not reach the wall of the ovary as do the main placental outgrowths. Upon the edges of the lateral outgrowths and upon the surfaces lying next the main outgrowths are borne the ovules (*fig. 15*). The ovules at the base and top of the ovary lie parallel to the axis of the flower, those in the middle lie at right angles to it, the intermediate ones having intermediate positions according to their place in the ovary.

The summits of the carpellary leaves broaden and coalesce, and grow out in a direction radial to the axis of the flower, so that while their basal parts form the capsule and the stalk of the style, the tips form the umbrella of the style (*fig. 3*). The tip of each carpellary leaf organizes a very definite growing-point (*fig. 28*), and the portion between the tips nearly keeps pace in growth. Upon the ventral surface of each tip, just before it completes its growth, is formed the protuberance which bears the stigmatic surface.

The appearance of the primordia of the ovules upon the placentae takes place from the point opposite the angle of the ovary wall, where the adajcent lateral outgrowths meet, successively toward the angle formed by the lateral outgrowth and the main outgrowth (*fig. 19*). In vertical direction the development proceeds from the middle of the placenta toward top and bottom. The ovules first appear as protuberances initiated by the periclinal division of subepidermal cells and the accompanying anticlinal division of the epidermal cells, as is commonly the case. When the ovule first protrudes from the placenta there is no suggestion of a sporogenous cell. At this stage of development the winter rest intervenes. The first suggestion of a sporogenous cell comes with the enlargement of a single subepidermal cell, which is the megaspore mother cell (*fig. 16*). In three cases out of many hundreds examined there were two mother cells lying side by side. There is no tapetal cell. The bending by which the ovule becomes anatropous begins at once, and is quite

marked by the time of the appearance of the mother cell. Both transverse and longitudinal sections (*figs. 16* and *17*) show a double layer of cells at the sides of the mother cell, and median longitudinal sections show approximately five rows of cells in the ovule, exclusive of the epidermis.

The integument is single, its development beginning by periclinal divisions of subepidermal cells upon the convex side of the bending ovule, and continuing as a ring which grows rapidly on the side where it began first and slowly on the opposite side, which lies next the raphe. The rapid growth of the ovule is accomplished largely by the chalazal end. By the time of the first division of the mother cell the bending of the ovule is completed, the integument has grown so as nearly to close the micropyle, and the mother cell has increased in size and encroached upon the nucellar tissue so as to lie next the epidermal cells over the entire distal end (*fig. 20*).

The difference in the time of appearance of the ovules upon the different parts of the placenta causes a difference in the degree to which the integuments develop (*fig. 19*), and also a difference in the maturation of the mother cell, and the germination of the megaspore in ovules in the different parts of the placenta, a difference which long remains evident.

At the first division of the mother cell it was not found possible to count the number of chromosomes. The division is followed by the formation of a wall (*fig. 20*), and in about half the cases observed both the daughter cells again divide to form the normal linear tetrad of megaspores (*fig. 23*). In the remaining cases the micropylar daughter cell fails to divide, resulting in a series of three megaspores (*fig. 21*); and much less frequently the micropylar daughter cell divides by a wall parallel or nearly parallel to the long axis of the nucellus (*fig. 22*). In any case it is the chalazal megaspore which functions, the micropylar ones being appressed to the layer of nucellus and absorbed. The maturation of the megaspore is coincident with the tetrad division of the microspore mother cells.

EMBRYO SAC.

Such has been the elongation of the ovule by the time the megaspore matures that the nucellus is lengthened five or six times its diameter,

being made up of slightly elongated cells five or six rows thick in median section. The integument, about five cells thick, has now grown well beyond the tip of the nucellus, and its lips have become somewhat appressed to form the long micropyle. The cells in the innermost layer in the integument show active division in the direction of the greatest length of the nucellus, and by their dense protoplasm and large nuclei stand out prominently as a definite layer which I shall designate as the "columnar tissue."

After the disappearance of the megaspore sister cells the definitive megaspore continues its absorptive activity to the destruction of the single layer of nucellus at its micropylar end, so that the distal half of it comes to lie directly against the columnar tissue of the integument. The chalazal end is pointed, occupies at this time a median position in the nucellus, and is apparently active in the degeneration of the nucellar tissue, in accommodation to its own growth. About this time the definitive megaspore undergoes division. The daughter nuclei take places at opposite ends of the embryo sac (*fig. 24*), and quickly undergo the second (*fig. 25*) and third divisions in the normal manner.

The mature embryo sac is typical in every respect. It is elongated to four or five times its width, the sides lie next the columnar tissue and the base continues to be pointed and median. The synergidae lie side by side and the egg protrudes a little way below them, nearer the center of the sac. The cytoplasm of the synergidae is dense and stains heavily with the Flemming triple; that of the egg is greatly vacuolated. The antipodals lie well together in the conical base of the sac (*fig. 26*). The polar nuclei meet midway between the ends of the sac, and after their fusion the endosperm nucleus continues to occupy this position (*fig. 26*). After the fusion of the polar nuclei the endosperm becomes very active in the disorganization of the remaining basal portion of the nucellus. In this activity the antipodals do not take part. The base of the sac remains pointed, but from being median now comes to lie against the columnar tissue at one side of the nucellus by means of the absorption of the nucellar tissue which lay between its previous position and the columnar tissue. The further enlargement of the sac is accompanied by a pushing downward of the base between the nucellus and columnar

tissue, and in some preparations the antipodals would seem to have been pushed to one side (*fig. 27*). The columnar layer now shows its maximum development, being made up of deep, much-flattened cells with darkly staining cytoplasm. The function of these cells is no doubt that of secreting and passing over to the sac sugars or other elaborated foodstuffs.

POLLINATION AND POLLEN TUBES.

Pollination takes place, near Baltimore, during the first week in May. In the mature style of Sarracenia at the time of pollination the umbrella is a pale green color. Its internal structure is leaf-like without a definite palisade, but with abundant intercellular spaces and stomata numerous upon the upper surface and few upon the lower. Long unbranched unicellular hairs cover the lower surface so thickly as to form a tomentum in which considerable pollen is caught at the time of shedding. There are also upon both sides of the umbrella multicellular glands of spheroidal shape projecting slightly above the level of the epidermis. Running from the five stigmatic surfaces toward the center of the umbrella are heavy veins which comprise both vascular and conducting tissue.

The union of the carpels in the formation of the stalk of the style is such as to leave at its center a pentagonal cavity which in the mature flower connects the interior of the capsule with the external air. An examination of the veins of the umbrella two weeks before pollination will show the conducting tissue as a cylindrical strand about ten cells in diameter. The cells are much elongated, with pointed ends, or many cells of this description have divided transversely to two or four cells. The cytoplasm is dense, the nuclei are large, elongated, often three times as wide as long, binucleolate, and poor in chromatin. At the time of the passage of the pollen tubes the conducting strand has become enlarged to more than twice its previous diameter at the expense of the surrounding tissue, and the cells have become still more elongated. The cytoplasm is much vacuolated, the nuclei are attenuate at the ends and devoid of nucleoli (*figs. 32, 33*), and there are large intercellular spaces. The vascular tissue of the veins lies beneath the conducting tissue and is continuous with the vascular tissue of the stylar stalk.

Two weeks before pollination transverse sections of the stalk of the style show five strands of heavy-walled cells running from the angles of the central cavity half way to the periphery (*fig. 34*). The tissue which these cells represent in cross section is four to six cells thick and runs the entire length of the stalk, being in the median line of the carpels. About the time of pollination these sheets of cells are found to split into two layers, which separate in such a manner as to form canals which are connected with the central cavity (*fig. 35*). The surface layer of cells on the interior of the canal becomes detached and undergoes partial degeneration. The five conducting canals thus formed are continuous with the conducting tissue of the veins of the umbrella above, and open below midway between the main placental outgrowths.

The stigmatic surface is richly provided with long, curved, heavy-walled outgrowths of epidermal cells (*fig. 31*), which serve to catch pollen and hold it. Pollen was found to be present in abundance on all stigmas examined. There is no definite sprouting-pore in the grains, but the tubes grow more commonly from the meridional grooves. The pollen tubes grow between the cells of the stigmatic surface and their entire passage is between the cells of the conducting tissue and never through them. They follow the well-defined course of the conducting tissue along the vein of the umbrella and down the stalk of the style (*fig. 30*).

The generative nucleus was not seen in any case to have divided before the sprouting of the pollen tube, and the earliest position in which it was seen to have divided was in a tube which had nearly reached the center of the umbrella. The tube nucleus is spherical and precedes the generative nuclei. The latter are alike in form—elongated and curved or often bent twice in serpentine manner. The distance of the nuclei from the end of the tube is four to six times the diameter of the tube. The cytoplasm is dense in the entire end and around the nuclei (*fig. 36*).

When the pollen tubes enter the cavity of the ovary from the five conducting tubes of the stalk, they are directly above the line of juncture of the two adjacent lateral placental outgrowths. The course of the pollen tubes is at first a downward one between these outgrowths, and later an outward one radial to the axis of the ovary

(*fig. 30*). In this manner the edges of the placentae are reached after a course in the ovary which, for the tubes growing to the lowermost ovules, is as much as 6 to 8^{mm}, and lies entirely outside the tissue of the plant in an ovary the cavity of which has direct communication with the external air. The epidermal cells of the placental surfaces between which the pollen tubes pass are densely filled with cytoplasm; beneath them lie three layers of flattened cells of similar contents. Thin transverse walls are formed in the tubes near the stigmatic surface (*fig. 37*), and far down in the ovary, near the ovules, plugs are not infrequent in the tubes, being three to six times the diameter of the tube in length.

The distance traversed by the pollen tubes which reach the lowermost ovules in flowers of average size, is about 4^{cm}. Provision for the nutrition of the tube during its growth and passage is perhaps made in part by the photosynthetic activity of the umbrella. Previous to pollination the epidermal, subepidermal, and some deeper cells of the umbrella are filled with densely-staining, finely granular contents. In fresh material of the same age the contents of these cells fail to react to tests for sugar made with Fehling's solution, a-naphthol and thymol, as well as to tests for starch. Similar contents fill the epidermal cells of the stalk of the style. The course of the tubes as far as their entrance to the ovary is doubtless through a strong solution of sugars. Below the point of entrance to the ovary the passage between the placental walls is probably through a film of sugary solution held there by capillarity and supplied with materials from the epidermal cells of the placental walls, which after pollination are highly vacuolated, in marked contrast to their condition before pollination.

FERTILIZATION.

The fusion of the male and female nuclei in fertilization is preceded by the division of the endosperm nucleus in nearly all the embryo sacs. Fertilization takes place, then, in all ovules at nearly the same time irrespective of a difference in the development of the endosperm due to the position of the ovule upon the placenta. As to the length of time intervening between pollination and fertilization I am unable to give any exact data. A visit on May 24 to plants

growing in the open found the anthers nearest the ovary to have shed their pollen. Material collected at the same locality two days later was found to show fertilization. The time of pollination of the particular flowers gathered and fixed may have been as much as five days before gathering, but was probably not earlier.

The thin-walled slender pollen tubes may be found in abundance about the mouths of the micropyles, often forming considerable masses. The cells which line the micropyle are heavy-walled and of such darkly-staining contents that it is difficult to observe the pollen tube within the micropyle, and indeed the entrance of the tip of the tube, with the nuclei, was not observed. The synergidae become appressed to the wall of the sac. The end of the tube upon entrance to the sac becomes expanded and pushes downward to one side of the egg. The generative nuclei have lost the elongated shape they were seen to have while passing down the style and have become spherical. Fusion of the first generative nucleus shows no special peculiarities (*fig. 38*).

ENDOSPERM.

The fusion of the polar nuclei is quickly followed by division. The first wall in the endosperm is transverse to the length of the sac and divides it into equal halves (*fig. 39*). The daughter nuclei divide in like manner (*fig. 40*), as do also the grandaughter nuclei, giving rise to an endosperm of eight cells in linear series, in which the walls are all transverse, although not uncommonly somewhat oblique (*fig. 41*). Subsequent divisions are less regular, and by the time the fertilized egg has divided the endosperm contains approximately 150 cells, its base having used up the nucellus either completely or all but a half dozen cells (*fig. 42*). At this time the endosperm cells are highly vacuolated and the laying down of food has not begun.

The relative rate of development of the endosperm in ovules upon different parts of the same placenta is the same as was noted with regard to the integuments. An ovule at the point of juncture of the adjacent lateral placental outgrowths may have an eight-celled endosperm at the same time that the endosperm nucleus has not yet divided in an ovule upon the edge of the placenta nearest the main placental outgrowth.

EMBRYO.

The first division of the fertilized egg is in a direction parallel with the length of the sac. The two-celled embryo (*fig. 43*), at first oval, becomes gradually elongated, divisions following in the same plane as the first, but not in a manner in which it has been possible to discover any regularity. After the embryo has attained a length of five to seven cells, there is a lateral division of the terminal cell (*fig. 44*), the beginning of the embryo proper. The suspensor is usually curved, though not always to so great an extent as shown in the figure. I have been unable by lack of material to observe stages in the development of the embryo immediately following the transverse division of the terminal cell.

In material of June 25 the embryo proper is found to have reached a size of approximately 250 cells, with ellipsoidal form (*fig. 45*). Dermatogen and periblem are well-defined, but no procambial cells have as yet appeared. The endosperm has by this time increased greatly in diameter, encroaching upon the tissue of the integuments. The endosperm cells have become well-stored with aleurone except in the central portion of the micropylar end—the region destined to be occupied by the full-sized embryo of the mature seed. In embryos as large as that shown in *fig. 45* the suspensor is surrounded by endosperm cells in which aleurone has been laid down; the embryo proper is surrounded by cells of highly vacuolated contents.

SEED AND SEEDLING.

Material gathered during the last week of July exhibits seeds which are practically mature. The embryo has grown to an elongated ellipsoidal form, the cotyledons being about one-third the length of the whole (*fig. 46*). Elongated procambium cells stretch from the basal end of the embryo to the region of the stem growing-point. Stomata are not formed in the embryo until the time of germination. A few endosperm cells at the sides and cotyledonary end of the embryo are free of aleurone, as they remain in the mature seed.

The surface layer of cells of the integument forms the seed coat. Its cells become irregular on their external surface and the walls are greatly thickened, with conspicuous pores in the lateral and basal walls, but none in the walls forming the surface of the seed

(*fig. 47*). The inner cells of the integument are all disorganized by the growth of the endosperm and reduced to a layer of the remaining walls of flattened cells. The raphe of the ovule develops into a wing upon one side of the seed, as seen in *fig. 47*. In the mature seed there is a coating of wax upon the surface which renders them unwettable, a condition in which they remain for several weeks after they have been placed in wet moss.

Provision for the shedding of the seed is made by a deep furrow surrounding the raphe just at its junction with the placenta (*fig. 48*). The dehiscence of the capsule is loculicidal and is provided for by a deep suture upon the external surface of the capsule wall at a point where the wall is traversed by a heavy vascular bundle. Dehiscence takes place late in September or early in October, the seeds are scattered gradually during many weeks by chance shaking of the scape by wind or animals. The old flower, with umbrella and sepals still persisting, is often found side by side with the bloom of the following year.

On germination the seed is elevated above the soil or moss by growth of the hypocotyl, which is sharply bent and is the first part of the seedling to protrude. The tips of the cotyledons remain for some time in the seed, functioning as haustoria for the removal of the stored food of the endosperm. The tips of the cotyledons are active in the removal of the endosperm both at their ends and along their sides (*fig. 49*). The cotyledons expand to liguliform leaves about 1^{cm} long (*fig. 50*), and persist until about the time of the formation of the third epicotyledonary leaf. The cotyledons develop stomata during the process of germination and the epidermal and subepidermal layers of isodiametric cells bear chlorophyll.

DEVELOPMENT OF LEAVES.

The stem growing-point of Sarracenia is massive and acutely dome-shaped in the seedling (*fig. 51*). There is a definite layer of dermatogen and a common group of initials for periblem and plerome. The first epicotyledonary leaf arises opposite the interval between the cotyledons. It is finger-shaped with a somewhat broadened base. On reaching a length about twice its diameter there begins a rapid lateral outgrowth of the tissue of an 0-shaped area on the

side of the leaf rudiment which faces the growing-point, giving rise to a pit which is destined to become the cavity of the pitchered leaf (*fig. 52*). The basal part of the 0-shaped outgrowth now begins to grow upward, in which it is accompanied at the same rate by the upper portion of the 0, which at the same time carries forward the apical growth of the leaf (*fig. 53*). The cavity of the pitcher thus grows in depth by the upward growth of the tissue by which it is surrounded. The bottom of the cavity is subsequently elevated to some extent by the further growth of the tissue beneath it, but there is no sinking of the bottom of the cavity, considered as a possibility by ZIPPERER.[2] The entire early development of the leaf resembles closely that which has been described for *Darlingtonia californica* by GOEBEL.[3]

The first epicotyledonary leaf reaches its maximum size at a length of about 2.5^{cm}, and is slender in form, the cavity reaching well down toward its base, and the wing being but slightly developed. At the summit it is hooded in such a manner as to resemble the mature leaf of *S. variolaris*. The walls of the pitchers of the seedling are six to eight cells in thickness, with open mesophyll, chlorophyll in all the cells, and stomata over the entire external epidermis. There are two principal strands of vascular tissue, one in the base of the wing and one on the opposite side of the pitcher, with smaller anastomosing strands between these. In the throat of the pitcher all the epidermal cells are produced into long projecting points; lower in the pitcher occasional epidermal cells, smaller than the others, give rise to long heavy-walled hairs, while in the bottom of the pitcher the epidermal and first layer of subepidermal cells are small and heavy-walled.

While each leaf of the young plant is passing through its period of most active growth, the internode between it and the next lower leaf is also elongating rapidly. A young leaf appears for this reason to arise from the petiole of the leaf below it (*fig. 51*). The relative elongation of the internodes is far greater in the seedling than in the adult plant.

The growth of a single plant from seedling to adult was not fol-

[2] Beitrag zur Kenntniss der Sarraceniaceen. Inaug. Diss. Erlangen. 1885.

[3] Pflanzenbiologische Schilderungen II. 5:73–92. *pls. 19–20*. 1893.

lowed, but evidence points to the time requisite for the seedling to reach blooming age as being five or six years. Seeds of the crop of 1901, which in October of that year were placed in sphagnum in a loosely covered glass vessel, germinated in July 1902, and now, after 33 months, have no pitchers measuring over 2^{mm} in diameter. The extremely artificial conditions under which these seedlings were kept would make it inadvisable, however, to draw from them any general conclusions as to the rate of growth in the seedlings under natural conditions. The great number of intermediate stages in growth between the seedling and adult which may be observed in a single locality at any one season would also argue for the slowness of the plant in reaching adult size.

The stem growing-point of the adult plant is more broadly dome-shaped than that of the seedling, but is identical with it in the mode of origin of the dermatogen, periblem, and plerome. The earliest primordium of the leaf is likewise more massive than in the seedling, but essentially similar. Its form is conical, with a broadly semi-circular base embracing the growing-point. Near the summit, upon the side toward the growing point, is developed the narrow pit which is destined to form the cavity of the pitcher, its origin being due wholly to a difference in the rate of growth of the tissue at the bottom of the pit and that forming its sides (*fig. 54*). BAILLON[4] in a brief note on the development of a Sarracenia (species not mentioned) has described this early stage and called attention to its similarity to an early stage in the development of peltate leaves, averring that "La membrane qui tapisse intérieurement l'urne n'est autre chose que l'épiderme supérieur de la feuille." This may be an entirely superficial analogy, or it may be a hint as to the ultimate origin of such a markedly modified leaf. GOEBEL (*l. c.*) has figured the early leaf primordium of *S. Drummondii*, which is essentially like that of *S. purpurea*.

With the continued growth of the leaf rudiment the pit becomes deeper, and its mouth becomes vertically elongated, although remaining very narrow. At stages somewhat earlier than that shown in *fig. 55*, the sides of the mouth of the pit have come together, closing it completely. *Fig. 55* represents a leaf primordium in which

[4] (Note on the development of leaf of Sarracenia) Adansonia **9**:380. 1870.

the wing is just beginning to appear. *Figs. 56–61* represent cross sections of the primordium at this age in the places indicated in *fig. 55.*

In older leaves, such as are represented in *fig. 62*, the base of the leaf primordium is stoutly crescentic in cross section. Through the groove at the inner side of the leaf base the next younger leaf appears (*figs. 55* and *62*). The groove becomes narrower and more shallow as we pass up the leaf and ends just short of the bottom of the cavity of the pitcher (*fig. 62*). Above the end of the groove there is a short portion of the young leaf which is circular in cross section, above which in turn the narrow flattened outgrowth of the wing has become more conspicuous. The wing rudiment ends rather abruptly at a point where retardation of growth in diameter indicates the line of demarcation between the pitcher and cover. The cavity of the pitcher at this stage reaches as far as the upper end of the circular portion of the base.

There have been many suggestions as to the homology of the parts of the pitchered leaf of Sarracenia. A view held by many is that the pitchered portion of the leaf is derived from the primordium of the petiole and the cover from the primordium of the lamina. GOEBEL (*l. c.*) points out that since there can be no distinction in the very young leaf of primordia of petiole and lamina there can be no line drawn as to what portions of the pitchered leaf "represent" these structures.

The anatomy of the mature leaf was first worked out by VOGL;[5] it has more recently been reviewed by GOEBEL (*l. c.*), and minor contributions have been made by SCHIMPER[6] (1882) and ZIPPERER (*l. c.*). The first leaf rudiments unfolded in the spring are aborted (*fig. 62*), consisting of the sheathing base surmounted by the minute retarded primordium of pitcher and cover. These are usually three in number, and may occur in plants which do not bloom, as well as in those which do. In the latter case the aborted leaves are those just above the one to which the flower appears to be axillary.

[5] Die Blätter der *Sarracenia purpurea*. Sitzungsb. Wiener Akad. Wiss. Math.-Naturw. 50:281-301. *pls. 2*. 1864.

[6] Notizen über insectfressende Pflanzen. Bot. Zeit. 40:225–234, 241–248. *pl. 4* (*figs. 1–3*). 1882.

The axillary buds of Sarracenia are commonly very small and consist of growing-point and the primordium of a single leaf, completely covered and protected by the sheathing leaf base. An occasional axillary bud develops, the first two leaves being opposite and on the opposite sides of a line connecting the growing-point of the bud with the center of the shoot. There is thus brought about a branching of the rhizome, which by frequent repetition gives rise to large clusters of individuals.

The anatomy of the rhizome of *S. purpurea* has been described by ZIPPERER in sufficient detail, since it presents no unusual fatures. He has also given a correct account of the growing-point of the root and the development of the vascular tissue of the root: the growing-point being of the type in which the cap and three tissue layers are all derived from a common group of initials; the early order of vascular bundles being triarch.

Root hairs are few upon the roots of plants growing in a saturated substratum in the open, but are abundant in seedlings grown in highly saturated sphagnum, and in adult plants in the open which are growing in a substratum merely moist. Mycorhiza has not been observed in *S. purpurea* in the vicinity of Baltimore, although fungal threads have been found covering the root of seedlings grown under the conditions previously mentioned and penetrating the epidermis. MACDOUGAL[7] (1899) has described penetration of the epidermis by hyphae in adult plants without committing himself as to their mycorhizal nature.

SUMMARY.

1. The flowers of *Sarracenia purpurea* are axillary, perfect, hypogynous, and radially symmetrical. The stamens are seventy to eighty in number and arise in ten groups. There are four microsporangia. There is a double layer of binucleate tapetal cells, derived from the primary archesporium. There are three to five parietal layers. The tetrad division is simultaneous; the microspore nucleus divides before the dehiscence of the anthers. The reduced number of chromosomes is twelve.

2. In the ovule there is a single archesporial cell, which is the megaspore mother cell. There is no tapetal cell. The ovule is

7 Symbiotic saprophytism. Annals of Botany 13:1–47. 1899.

anatropous and there is a single integument. The megaspore mother cell divides to a linear series of four megaspores, or after the first division the micropylar nucleus may fail to divide or may divide by a wall longitudinal to the ovule.

3. The chalazal megaspore is functional, and develops a typical eight-celled embryo sac. The polar nuclei fuse and the endosperm may become two to eight-celled before the complete fusion of male and female nuclei in fertilization.

4. The pollen tube grows through a definite conducting tissue in the upper expanded portion of the style, through schizogenic canals in the stalk of the style and between the placental outgrowths in the ovary. The generative nucleus divides before the tube has passed into the stalk of the ovary. Fertilization presents no peculiarities.

5. The embryo is elongated and straight, with cotyledons. The storage tissue is endosperm filled with aleurone. The seed coat is the external layer of the integument. The cotyledons function as haustoria in germination and survive as chlorophyl-bearing leaves.

6. The first epicotyledonary leaf is pitchered and arises from a finger-like primordium in which a cavity is developed by unequal growth.

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EXPLANATION OF PLATES III–V.

Abbreviations used: *ant*, antipodal; *arsp*, archesporium; *br*, bract; *cav*, cavity; *col t*, columnar tissue; *con c*, conducting canal; *con s*, conducting strand; *con t*, conducting tissue; *cot*, cotyledons; *cov*, cover; *cp*, carpel; *der*, dermatogen; *d s*, dehiscing slit; *e*, egg; *em*, embryo; *en n*, endosperm nucleus; *e s*, embryo sac; *esp*, endosperm; *f n*, female nucleus; *g n*, generative nucleus; *int*, integument; *int i*, integument initials; *l*, leaf; *l p o*, lateral placental outgrowth; *meg mc*, megaspore mother cell; *meg sc*, megaspore sister cell; *mic mc*, microspore mother cell; *micsp*, microsporangium; *mn*, male nucleus; *m p o*, main placental outgrowth; *nuc*, nucellus; *ov*, ovary; *par c*, parietal cells; *pet*, petals; *pn*, polar nuclei; *ppi*, initials of periblem and plerome; *pro c*, procambium cells; *sc*, seed coat; *sep*, sepal; *st*, stamen; *stg s*, stigmatic surface; *stk*, stalk of style; *sus*, suspensor; *syn*, synergid; *tap c*, tapetal cells; *tn*, tube nucleus; *um*, umbrella of the style; *w*, wing.

All figures are camera drawings fom microtome sections except *figs. 29, 30, 50, 55*, and *62*, which are from free-hand drawings.

PLATE III.

FIG. 1. Vertical section of young flower bud. ×30.

FIG. 2. Transverse section of young flower bud of same age as in *fig. 1;* dotted outline represents position of carpel tips in higher sections. ×30.

FIG. 3. Vertical section of older flower bud. ×30.

FIG. 4. Transverse section of young stamen. ×232.

FIG. 5. Transverse section of single microsporangium of older stamen. ×232.

FIG. 6. Tranverse section of portion of microsporangium and wall in microspore mother cell stage. ×400.

FIG. 7. Transverse section of portion of microsporangium and wall with microspore mother cells in synapsis. ×232.

FIG. 8. Transverse section of mircosporangium and portion of wall; pollen mother cells in mitosis. ×400.

FIG. 9. Pollen mother cells in metaphase of first mitosis. ×400.

FIG. 10. Tetrads of microspores. ×400.

FIG. 11. Pollen grain. ×400.

FIG. 12. Pollen grain after division of nucleus. ×400.

FIG. 13. Transverse section of mature anther. ×20.

FIG. 14. Transverse section of young ovary. ×20.

FIG. 15. Transverse section through middle of nearly mature ovary. ×7.

FIG. 16. Longitudinal section of ovule with megaspore mother cell. ×400.

FIG. 17. Transverse section of ovule through megaspore mother cell. ×400.

FIG. 18. Longitudinal section of ovule with megaspore mother cell and integument. ×232.

FIG. 19. Transverse section of single lateral placental outgrowth, showing difference in rate of development of integument on different parts of the placenta; somewhat diagrammatic. ×40.

PLATE IV.

FIG. 20. First maturation division of megaspore mother cell. ×400.

FIG. 21. Linear series of three megaspores, arising by failure of micropylar daughter cell to divide. ×400.

FIG. 22. Tetrad of megaspores in which the micropylar daughter cell has divided longitudinally. ×400.

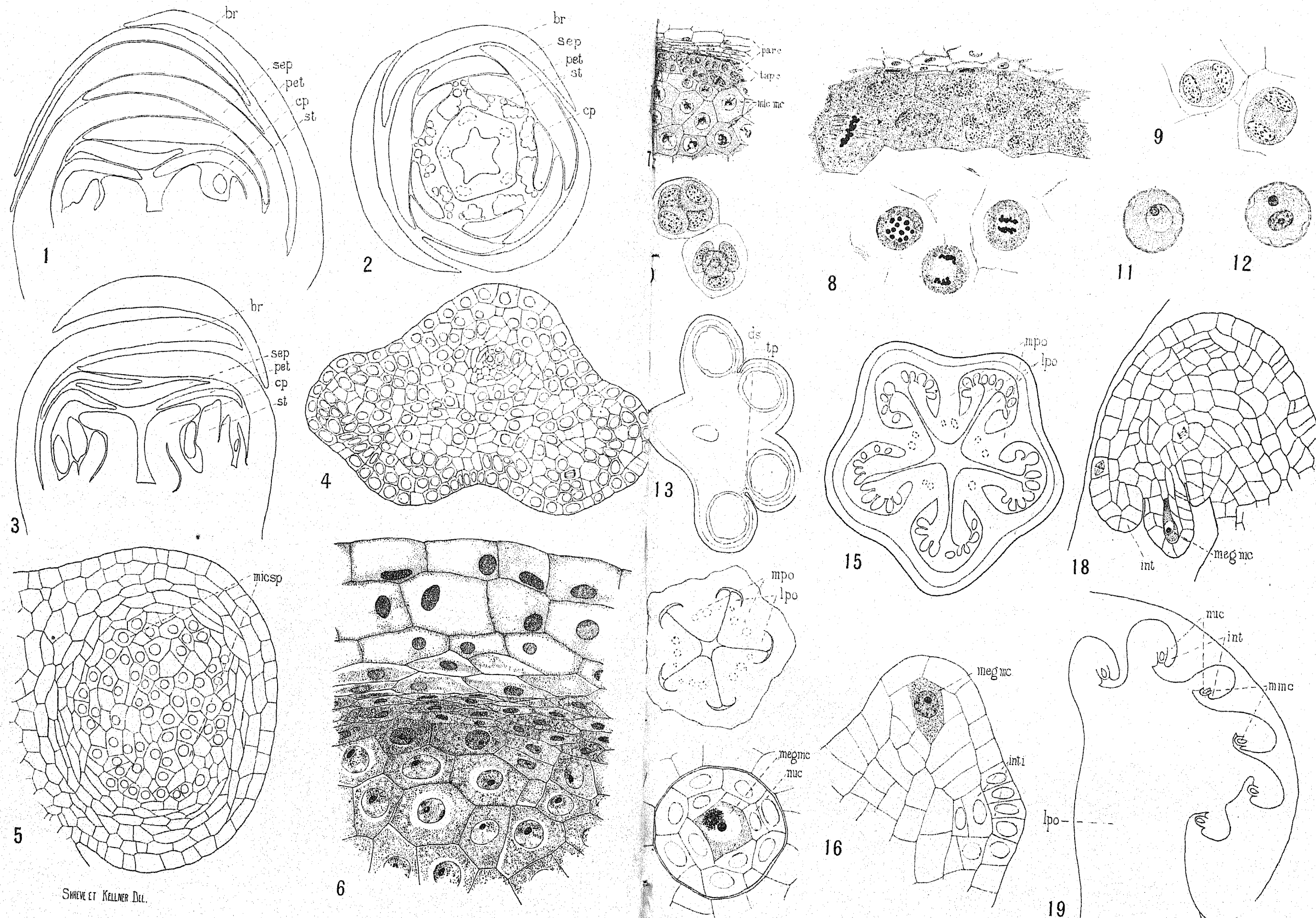
FIG. 23. Longitudinal section of ovule, with tetrad of megaspores, chalazal one enlarging and encroaching on single layer of nucellus. ×120.

FIG. 24. Longitudinal section of portion of ovule showing two-celled embryo sac, nucellus, and columnar tissue. ×232.

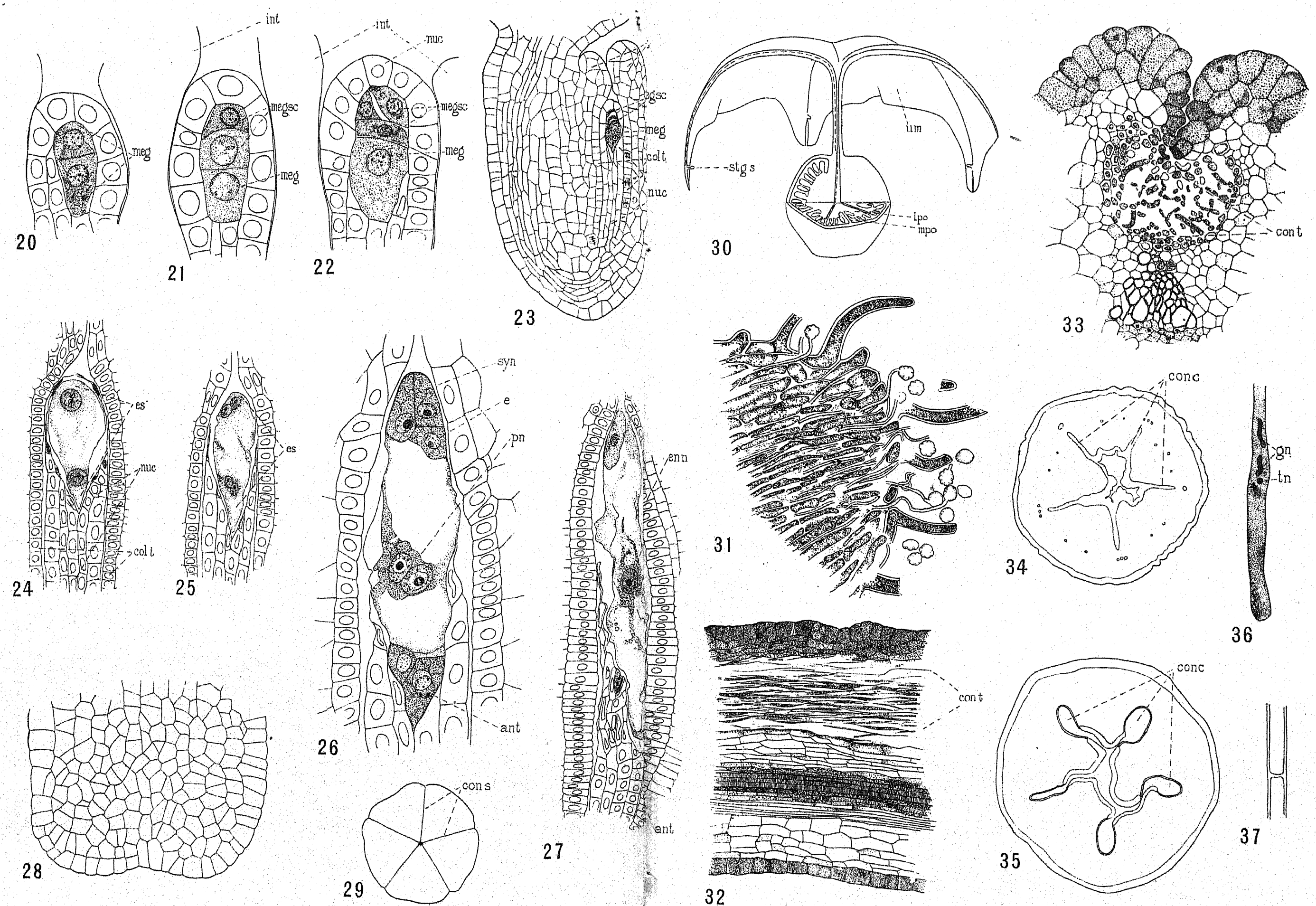
FIG. 25. Longitudinal section of portion of ovule showing four-celled embryo sac. ×232.

FIG. 26. Longitudinal section of portion of ovule showing fully developed embryo sac. ×400.

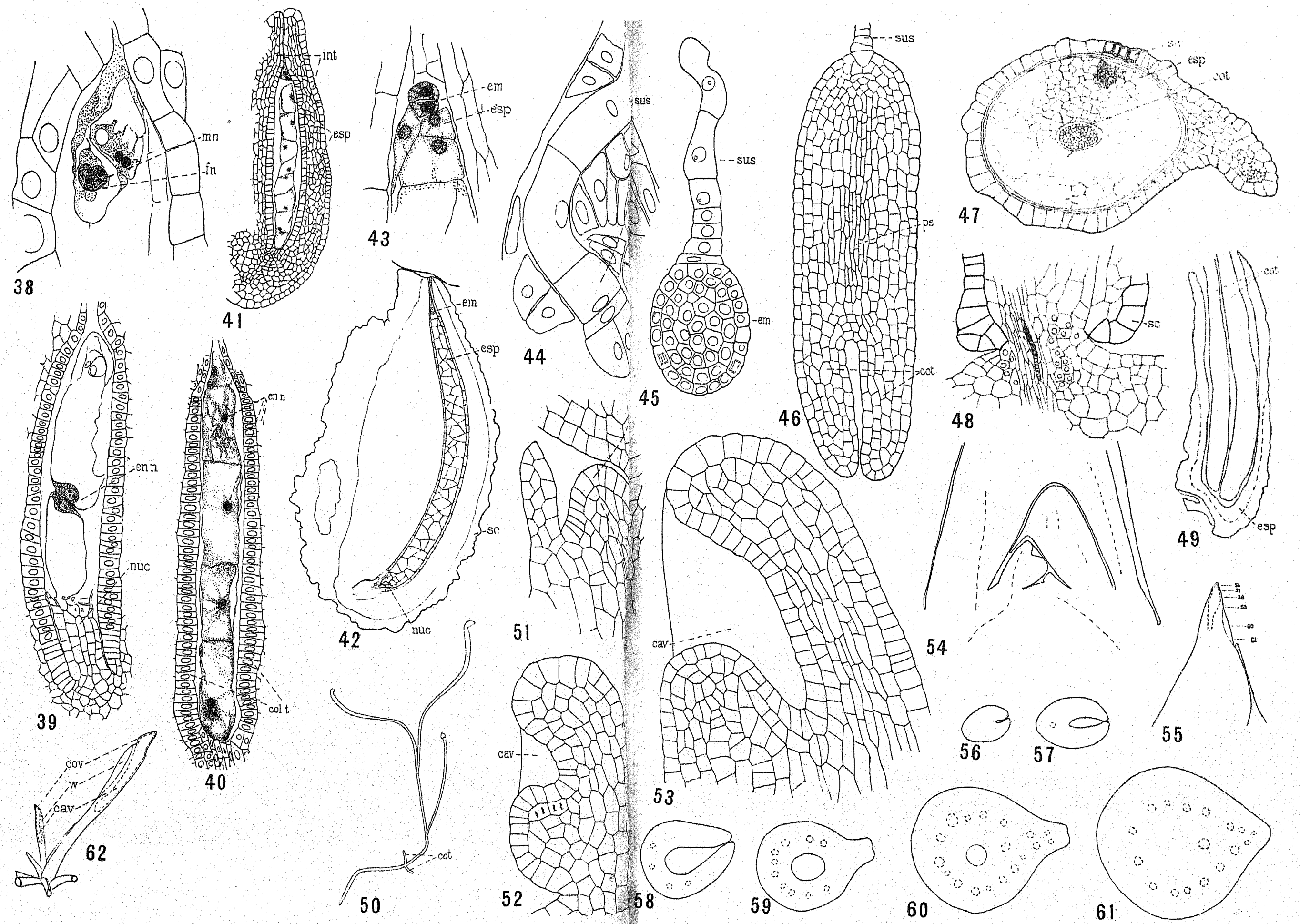
FIG. 27. Longitudinal section of portion of ovule showing embryo sac after fusion of polar nuclei; antipodals pushed to one side. ×232.



SHREVE on SARRACENIA



SHREVE on SARRACENIA



SHREVE on SARRACENIA

FIG. 28. Growing point of tip of carpel in umbrella, horizontal section. ×40.

FIG. 29. Stylar umbrella viewed from above; in outline. ×$\frac{2}{3}$.

FIG. 30. Ovary and style to show the course of pollen tube indicated by dotted line; somewhat diagrammatic. ×2.

FIG. 31. Longitudinal section of stigmatic surface with sprouting pollen grains. ×120.

FIG. 32. Longitudinal section of conducting strand in umbrella of style showing conducting and vascular tissue. ×40.

FIG. 33. Transverse section of upper surface of umbrella of style showing conducting and vascular tissue and glandular epidermis. ×120.

FIG. 34. Transverse section of stalk of style before pollination. ×20.

FIG. 35. Transverse section of stalk of style at time of pollination. ×20.

FIG. 36. Tip of pollen tube from conducting tissue of umbrella; optical section. ×400.

FIG. 37. Cross wall in tube near stigmatic surface. ×400.

PLATE V.

FIG. 38. Longitudinal section of upper end of embryo sac showing fusion of male and female nuclei. ×400.

FIG. 39. Longitudinal section of embryo sac showing two-celled endosperm, columnar tissue, and remains of nucellus. ×120.

FIG. 40. Longitudinal section of embryo sac showing four-celled endosperm. ×120.

FIG. 41. Longitudinal section of portion of ovule showing eight-celled endosperm and integument. ×40.

FIG. 42. Longitudinal section of seed through the wing showing multicellular endosperm and two-celled embryo. ×20.

FIG. 43. Two-celled embryo. ×232.

FIG. 44. Young embryo with suspensor. ×400.

FIG. 45. Older embryo with suspensor. ×232.

FIG. 46. Longitudinal section of embryo from mature seed. ×120.

FIG. 47. Tranverse section of mature seed cutting the embryo through the cotyledons; detail partially filled in. ×40.

FIG. 48. Longitudinal section through the hilum of nearly mature seed. ×120.

FIG. 49. Longitudinal section of germinating seed, with cotyledons; seed coat has been removed; portion beyond the dotted line is that from which aleurone has not yet been removed. ×20.

FIG. 50. Seedling with cotyledons and three epicotyledonary leaves. ×1.5.

FIG. 51. Vertical section through growing-point of seedling. ×232.

FIG. 52. Median vertical section through primordium of first epicotyledonary leaf. ×232.

FIG. 53. Median vertical section through portion of primordium of first epicotyledonary leaf in later stage of development. ×232.

FIG. 54. Vertical section through growing point and young leaves in adult plant. ×20.

FIG. 55. Surface view of primordium of leaf seen from the side, next younger leaf also showing; dotted outline marks cavity of leaf. ×3.

FIG. 56. Transverse section of leaf in *fig. 55* at *56*. ×20.

FIG. 57. Transverse section of leaf in *fig. 55* at *57*. ×20.

FIG. 58. Transverse section of leaf in *fig. 55* at *58*. ×20.

FIG. 59. Transverse section of leaf in *fig. 55* at *59*. ×20.

FIG. 60. Transverse section of leaf in *fig. 55* at *60*. ×20.

FIG. 61. Transverse section of leaf in *fig. 55* at *61*. ×20.

FIG. 62. Later stages of young leaves; cavities shown by dotted outline. ×1

ON THE IMPORTANCE OF PHYSIOLOGICALLY BALANCED SOLUTIONS FOR PLANTS.[1]

I. MARINE PLANTS.

W. J. V. OSTERHOUT.

RINGER demonstrated that animal tissues live longer in a solution of NaCl to which a small amount of KCl and $CaCl_2$ is added than in a solution of NaCl alone. Various explanations of this fact were given by different investigators, all of whom, however, agreed upon the essential point that KCl and $CaCl_2$ are essential for the maintenance of life.

HOWELL assumed that $CaCl_2$ is the stimulus for the heart beat, while NaCl is an indifferent substance, necessary only for the maintenance of osmotic pressure. Similarly RINGER concluded that Ca is the stimulus for the systole, while K is necessary for the diastole of the heart beat.

HERBST made experiments on the influence of the composition of the sea water on sea urchin eggs, eliminating in each successive experiment a different constituent of the sea water. He found that the eggs would not develop in any solution which did not contain all the salts of the sea water. From this he concluded that each of the salts found in sea water is necessary for the development of the egg. LOEB called this view in question as the result of his experiments on Fundulus. He found that this marine fish cannot live in a pure NaCl solution of the same osmotic pressure as the sea water, but that it can live indefinitely in a mixture of NaCl, KCl, and $CaCl_2$, in the same proportions in which these salts are contained in sea water. The fish can also live indefinitely in distilled water. This proves that it does not need any of the three salts mentioned for the maintenance of its life, and that the Ca and K are only required to overcome the poisonous effects which would be produced by the NaCl if it alone were present in the solution (at the above mentioned concentration).

[1] I wish here to express my sincere thanks to Professor LOEB, who kindly placed the facilities of his laboratory at my disposal and assisted me in every way during these investigations.

It is noteworthy that the Ca and K, which are added to inhibit the toxic effect of NaCl, are themselves poisonous at the concentration at which they are here employed.

These antagonistic effects of Ca and K toward a pure NaCl solution were illustrated still more strikingly in experiments on the egg of Fundulus. The newly fertilized eggs of this fish develop equally well in sea water and in distilled water, but die in a pure $m/2$ NaCl solution without forming an embryo. If, however, a small but definite amount of a salt with a bivalent kation, even of such poisonous salts as $BaCl_2$, $ZnSO_4$, and $Pb(CH_3\text{-}COO)_2$, is added, the eggs will produce embryos. From these and similar observations LOEB was led to formulate his conception of the necessity of physiologically balanced salt solutions, in which are inhibited or counteracted the toxic effects which each constituent would have if it alone were present in the solution.

The blood, the sea water, and to a large extent RINGER'S solution, are such physiologically balanced salt solutions. The observations of HERBST, as well as those of RINGER, are easily explained on this basis. The fact that the elimination of any one constituent from the sea water makes the solution unfit to sustain life does not prove that the eliminated substance is needed by the animal for any purpose other than to counteract the poisonous action of some other constituent of the solution.

Botanists have not thus far made use of these conclusions, for the obvious reason that facts similar to those mentioned above have not been observed in plants. I have recently made a number of experiments which show that there exist in plants phenomena similar to those observed by LOEB on Fundulus and other marine animals.

The species of marine plants chosen for investigation may be divided into two groups:

Group 1 comprises plants which can live a long time in distilled water. It includes the following: BLUE-GREEN ALGAE, Lyngbya aestuarii; GREEN ALGAE, Enteromorpha Hopkirkii; FLOWERING PLANTS, Ruppia maritima.

Group 2 is composed of plants which quickly die in distilled water. It includes the following: GREEN ALGAE, Enteromorpha intestinalis; BROWN ALGAE, Ectocarpus confervoides; RED ALGAE,

Ptilota filicina, Pterosiphonia bipinnata, Iridaea laminarioides, Sarcophyllis pygmæa, Nitophyllum multilobum, Porphyra naiadum, Porphyra perforata, Gelidium sp., Gymnogongrus linearis, Gigartina mammillosa.[2]

If plants of either group be placed in a solution of pure sodium chlorid (isotonic with sea water), they die in a short time. This might be attributed to the lack of certain salts which are necessary for their metabolism, rather than to the toxicity of the sodium chlorid. In the case of the plants of Group 1 there can be no doubt on this point, for these plants live a long time in distilled water. If we add pure sodium chlorid to the distilled water it kills them in a very short time. An inspection of the tables will show that these plants in their behavior toward sodium chlorid and other salts, closely agree with those of Group 2, which can live but a short time in distilled water. Sodium chlorid is certainly toxic to the first group, and there can be little doubt that it is so to the second group as well.

The plants of the first group were found in a ditch in a salt marsh through which the tide ebbs and flows; there is always a foot or so of water even at low tide. The salt content of the water fluctuates around a mean of approximately 2.3 per cent.

The plants of the second group were collected at the entrance to San Francisco Bay, where the salt content of the water fluctuates about a mean which is probably not far from 2.7 per cent. The only exceptions are *Enteromorpha intestinalis* and *Ectocarpus confervoides*, which came from wharves in the bay, where the mean salt content is about 2.3 per cent.

All the plants used in the experiments were transferred from the sea water directly to distilled water. After rinsing in this they were placed in glass dishes, each containing 200^{cc} of the solution to be tested. The dishes were then covered with glass plates to exclude dust and check evaporation. Only a small amount of material was placed in each dish. The temperature during the experiments did not vary far from 18° C.

Artificial sea water was prepared[3] according to VAN 'T HOFF'S

[2] The determinations were kindly made by Professor SETCHELL.

[3] The water used was distilled in glass only and the first part of the distillate rejected. The purity of each salt was carefully tested before using.

formula[4] as follows: 1000^{cc} NaCl, $3m/8$; 78^{cc} $MgCl_2$, $3m/8$; 38^{cc} $MgSO_4$, $3m/8$; 22^{cc} KCl, $3m/8$; 10^{cc} $CaCl_2$, $3m/8$.[5]

This closely approximates the bay water. The plants thrive almost as well in it as in sea water, especially when a very little $NaHCO_3$ or $KHCO_3$ is added to produce a neutral or faintly alkaline reaction.

A series of solutions was tried, beginning with pure NaCl $3m/8$ and adding to it in turn $MgCl_2$, KCl, and $CaCl_2$, either singly or in combination, in the proportions given above. These salts were also used in pure solutions of the same concentration at which they exist in the artificial sea water described above.

It should be said that little difficulty was experienced in determining the death point with sufficient precision. The color reactions and the microscopic appearance of the cells allowed this to be done with sufficient accuracy, so that the results were not in doubt on this account.

The results of the experiments are set forth in the tables. The figures represent the average of four parallel series carried on simultaneously. A control series was also carried on in which each solution was made faintly alkaline by the addition of $NaHCO_3$, $KHCO_3$, or $Ca(OH)_2$. This had a beneficial effect during the first two or three days of the experiment, but the final results were practically the same as in the other series.

From a consideration of the results for Group I we may draw the following conclusions.

1. The plants die much sooner in a pure sodium chlorid solution (isotonic with sea water) than in distilled water. The poisonous effect of the NaCl largely disappears if we add a little $CaCl_2$ (10^{cc} $CaCl_2$ $3m/8$ to 1000^{cc} NaCl $3m/8$); in this mixture the plants live nearly as long is in distilled water. Addition of KCl to this mixture enables them to live longer than in distilled water. Further addition of $MgCl_2$ and $MgSO_4$ enables them to live practically as long as in sea water.

[4] VAN'T HOFF, J. H., Physical chemistry in the service of the sciences 101. Univ. of Chicago Press, 1903.

[5] This corresponds approximately to the proportion of Ca in the sea water of the bay.

TABLE I.

DURATION OF LIFE IN DAYS.

Culture solution.	Group 1			Group 2		
	Lyngbya aestuarii	Enteromorpha Hopkirkii	Ruppia maritima	Ptilota filicina	Pterosiphonia bipinnata	Iridæa laminarioides
Sea water (total salts 2.7 %)	95	150+	150+	11	$24\frac{1}{2}$	24
Artificial sea water: 1000 cc NaCl $3m/8$ 78 " $MgCl_2$ " 38 " $MgSO_4$ " 22 " KCl " 10 " $CaCl_2$ "	90	150+	150+	$10\frac{1}{2}$	$24\frac{1}{2}$	23
Distilled water.........	30	30	80	1	$3\frac{1}{2}$	$2\frac{1}{2}$
Tap water.............	32+	36	85	$2\frac{1}{2}$	$9\frac{1}{2}$	10
NaCl $3m/8$	22	15	23	$1\frac{1}{4}$	$3\frac{1}{2}$	4
1000 cc NaCl " 10 " $CaCl_2$ "	29	23	65	$2\frac{1}{2}$	6	5
1000 " NaCl " 22 " KCl " 10 " $CaCl_2$ "	35	32	88	$3\frac{1}{2}$	10	9
1000 " NaCl " 78 " $MgCl_2$ " 10 " $CaCl_2$ "	29	23	45	3	6	6
1000 " NaCl " 78 " $MgCl_2$ " 22 " KCl "	25	$13\frac{1}{2}$	30	2	4	4
1000 " NaCl " 22 " KCl "	23	$13\frac{1}{2}$	23	1	2	5
1000 " NaCl " 78 " $MgCl_2$ "	$22\frac{5}{6}$	$13\frac{1}{2}$	25	$1\frac{1}{2}$	2	2
1000 " Dist. H_2O 78 " $MgCl_2$ "	$15\frac{1}{2}$	$16\frac{1}{2}$	19	1	2	$2\frac{1}{4}$
1000 " Dist. H_2O 38 " $MgSO_4$ "	$17\frac{1}{2}$	13	23	1	2	2
1000 " Dist. H_2O 22 " KCl "	21	$13\frac{1}{2}$	56	1	$1\frac{5}{6}$	$5\frac{1}{3}$
1000 " Dist. H_2O 10 " $CaCl_2$ "	26+	$12\frac{1}{2}$	58	$2\frac{1}{2}$	5	2

TABLE II.

DURATION OF LIFE IN DAYS. GROUP 2.

CULTURE SOLUTION.	Enteromorpha intestinalis	Ectocarpus confervoides	Sarcophyllis pygmæa	Nitophyllum multilobum	Porphyra naiadum	Porphyra perforata	Gelidium sp.	Gymnogongrus linearis	Gigartina mammillosa
Sea water (total salt 2.7 %.)	240	25	11	4½	6	21	33+	11	11
Artificial sea water: 1000 cc NaCl $3m/8$, 78 " $MgCl_2$ ", 38 " $MgSO_4$ ", 22 " KCl ", 10 " $CaCl_2$ ".	220	20	7½	4½	6	20	33+	10	9¼
Distilled water	3	1¼	1⅚	2½	2½	3⅓	1⅚	2½	3½
Tap water	10	2¼	3¾	3¾	2½	4½	5½	4½	5¼
NaCl $3m/8$	4¾	⅔	1⅔	⅚	2⅙	3	3	5⅚	2½
1000 cc NaCl ", 22 " KCl ", 10 " $CaCl_2$ "	68	8	5½	3½	5	14⅙	33+	9	6
1000 " Dist. H_2O, 22 " KCl "	4¾	4	1⅚	..	4¾	3	3	4	3

2. The pure solution of each of the salts added to inhibit the poisonous effects of NaCl is itself poisonous at the concentration at which it exists after its addition, since the plants die in such a solution much sooner than in distilled water.[6] A mixture of solutions which are individually poisonous produces a medium in which the plants live indefinitely.

That the plants die so quickly in solutions containing a single salt might be attributed to the fact that the osmotic pressure of some of these solutions is much lower than that of sea water. This supposition is disproved by the fact that in general the plants live longer in tap water than in any solution containing but a single salt, although the tap water has a lower osmotic pressure than that of any solution used in the experiments. (The plants of Group 1 live longer in distilled water also. The tap water is to be regarded as a physi-

[6] This statement does not apply in all cases to $CaCl_2$, which is the least toxic of the salts employed and for some forms quite harmless in dilute solutions.

ologically balanced solution; this will be more fully discussed in the second portion of the paper.)

3. The poisonous effect of NaCl is inhibited little or not at all by KCl or $MgCl_2$ added singly.

4. The combination $NaCl+KCl+CaCl_2$ is superior to $NaCl+MgCl_2+CaCl_2$, but the latter is better than $NaCl+MgCl_2+KCl$.

5. These effects must be due to the metal ions, since the anion is in nearly all cases the same.

The plants of Group 2 agree with those of Group 1 except in their behavior toward distilled water.

Essentially similar results were obtained from the study of fresh water algae and other plants, the details of which will be given in the second part of this paper.

These results agree in striking fashion with those obtained from the study of marine[7] and freshwater animals[8].

The combination $NaCl+KCl+CaCl_2$ (in the same proportions as in sea water) seems to be quite generally beneficial for animals and plants.

We may in conclusion briefly consider the effects of concentrated solutions. A series of experiments were made on *Enteromorpha Hopkirkii* in which the plants were placed in dishes with a very little sea water. This quickly evaporated, so that the plants became covered with salt crystals in 24 to 48 hours. In this condition some of them remained alive for about 150 days. This means that Enteromorpha plants which remain alive only 15 days in $3m/8$ NaCl solution can live 150 days in an NaCl solution of 10 to 12 times higher concentration, provided the other salts of the sea water are present in the solution (at corresponding concentration) to inhibit the toxic effect of NaCl. Experiments on Lyngbya, Ptilota, and Pterosiphonia gave essentially the same results.

In view of these results, and others of a similar character shortly to be published, it appears certain that physiologically balanced salt solutions have the same fundamental importance for plants as for animals.

7 LOEB, Pflüger's Archiv **107**:252. 1905, and the literature there cited.

8 OSTWALD, Pflüger's Archiv **106**:568. 1905. Univ. of California Publications, Physiology **2**:163. 1905.

RESULTS.

1. Each of the salts of the sea water is poisonous where it alone is present in solution.

2. In a mixture of these salts (in the proper proportions) the toxic effects are mutually counteracted. The mixture so formed is a physiologically balanced solution.

3. Such physiologically balanced solutions have the same fundamental importance for plants as for animals.

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THE APPRESSORIA OF THE ANTHRACNOSES.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXXXIV.

HEINRICH HASSELBRING.

(WITH SEVEN FIGURES)

IN describing a number of new plant diseases in 1883 FRANK[1] gave an account of peculiar spore-like organs produced by the germ tubes of spores of the bean anthracnose. He showed further that these organs acted as holdfasts, by means of which the fungus was firmly attached to its host during the early phase of development. In the same paper he described analogous organs of *Fusicladium Tremulae* and *Polystigma rubrum*. Almost simultaneously FISCH[2] described the holdfasts of Polystigma, but he did not at all recognize their true significance. He regarded them as "secondary spores" which served in the distribution of the fungus, since the ascospores are embedded in slime when ejected, and are therefore not suited for dissemination by the wind. FRANK first recognized the true nature of these bodies, and gave to all organs of this class the name *appressoria* or adhesion organs. Later MEYER[3] again described and figured the adhesion organs of Polystigma, but added no new observations. In 1886 DE BARY[4] first showed that the complex adhesion organs of Sclerotinia were produced as the result of a mechanical stimulus, but BÜSGEN[5] made the most complete study from a physiological standpoint. He showed that the germ tubes of many parasitic fungi produce adhesion organs of

[1] FRANK, B., Ueber einige neue und weniger bekannte Pflanzenkrankheiten. Ber. Deutsch, Bot. Gesells. 1:29–34, 58–63. 1883; Landw. Jahrb. 12:511–539. *pls. 3.* 1883.

[2] FISCH, C., Beitrage zur Entwickelungsgeschichte einiger Ascomyceten. Bot. Zeit. 40:851–870. *pls. 2.* 1882.

[3] MEYER, B., Untersuchungen über die Entwickelung einiger parasitischer Pilze bei saprophytischer Ernährung. Landw. Jarhb. 17:915–945. *pls. 4.* 1888.

[4] DE BARY, A., Ueber einige Sclerotinien und Sclerotinien-krankheiten. Bot. Zeit. 44:377 et seq. 1886.

[5] BÜSGEN, M., Ueber einige Eigenschaften der Keimlinge parasitischer Pilze. Bot. Zeit. 51:53. 1893.

various forms, and that their formation is due to a mechanical stimulus resulting from contact of the germ tube with some solid body.

These accounts seem to have escaped entirely the notice of American writers on the bitter rot, as is indicated by the many speculations and by the curious interpretations of the characteristic adhesion organs of the bitter-rot fungus and of other anthracnoses. The first economic account of the bitter rot appears in the *Report* of the chief of the Section of Vegetable Pathology for 1887.[6] Here the formation and germination of the appressoria are described. They are regarded as secondary spores, but no particular function is attributed to them. Excellent figures are also given on *plate 3* of the *Report* of 1890[7]. In 1891 Miss E. A. SOUTHWORTH[8] published the most complete account of the fungus up to that time. Regarding the "secondary spores" Miss SOUTHWORTH says: "What the conditions were that decided their appearance could not be determined. They were produced both in nutritive media and water, but seemed to be especially numerous where the ends of the hyphae came in contact with some hard substance like the cover-glass, and in two cases the addition of an extra drop of nutritive medium had the effect of stopping their formation." As to their function nothing is said, except that they are regarded as resting spores. (See *note*, p. 142.) In 1892 HALSTED published a short account of the secondary spores of anthracnoses.[9] He extends the list of anthracnoses which produce these organs to twenty-five species, including members of both Gloeosporium and Colletotrichum. ALWOOD[10] describes the production of "resting spores" by the bitter-rot fungus, but from his figures and description it is impossible to determine whether he had before him the bodies in question. Other writers have followed these investigators in their interpretation of the peculiar adhesion

[6] SCRIBNER, F. LAMSON, Bitter rot of apples. Rep. Sect. Vegt. Path. U. S. Dept. Agr. **1887**:348–350.

GALLOWAY, B. T., Ripe rot of grapes and apples. *Idem*. **1890**:408

[8] SOUTHWORTH, E. A., Ripe rot of grapes and apples. Journ. Myc. **6**:164–173. *pl. 1*. 1891.

[9] HALSTED, B. D., The secondary spores in anthracnoses. N. J. Agr. Exp. Sta. Rep. **1892**:303.

[10] ALWOOD, W. B., Ripe or bitter rot of apples. Agr. Exp. Sta. Va. Bull. 40. 1894.

organs of Gloeosporium. CLINTON[11] regards them as chlamydospores. They are also briefly described by VON SCHRENK and SPAULDING[12] who add *Gloeosporium cactorum* to the list of anthracnoses producing them. In order to clear up the uncertainty expressed in the literature regarding these organs, the following experiments and observations on the appressoria of *Gloeosporium fructigenum* are here recorded.

FORMATION OF APPRESSORIA.

As has been said, DE BARY and BÜSGEN have shown that the stimulus of mechanical contact is the cause of the formation of adhesion organs. Regarding the adhesion organs of Gloeosporium Miss SOUTHWORTH mentions the fact that they are especially numerous where a hypha comes into contact with some hard object like the cover glass. HALSTED finds that a rich nutrient medium produces only a meager supply of "special cells," while pure water increases their production. In neither case were these suggestions further investigated. Other writers had suggested in a general way that "unfavorable conditions" and starvation of mycelium cause the formation of the special cells.

Spores were sown in convex drops of water on slides kept in a moist chamber. Under these conditions the spores germinate rapidly, but their behavior varies according to their position in the drops. Those which sink to the bottom of the drop form a short germ tube, which enlarges into a round or pear-shaped disc when it comes into contact with the glass. In 12 to 18 hours this disc has developed into a complete adhesion organ (*fig. 1*). It is a brown spore-like body, having a thick wall which is perforated on its lower appressed surface with a very distinct germ pore. The adhesion

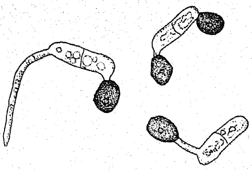


FIG. 1.—Appressoria formed by spores germinating in water on glass slides.

[11] CLINTON, G. P., Apple rots in Illinois. Univ. of Ill. Agr. Exp. Sta. Bull. 69. *pls. 10.* 1902.

[12] VON SCHRENK and SPAULDING, The bitter rot of apples. U. S. Dept. Agr. Bur. Plant Industry Bull. 44. *pls. 9.* 1903.

organs are so firmly fixed to the slide that they are not easily washed off by a jet of water. Other spores remain floating in the drops of water, being held by the surface film. These also germinate readily, but they never form adhesion discs while the germ tubes remain free in the water. Other spores were sown in drops of water placed on the surface of apples. These behaved in the same way as those on slides. Spores in hanging drops produced mostly mycelia, since very few germ tubes came into contact with the glass. The experiment was then varied by substituting beet infusion for the drops of water. The result was striking. The germ tubes produced no appressoria, but grew out into long hyphae, regardless of the fact that they were often in contact with the surface of the glass or with the cuticle of the apple. When sown in nutrient media of any kind, solid or liquid, the spores of Gloeosporium germinate and form mycelia directly.

These experiments show that the formation of appressoria is induced by a contact stimulus, but in the presence of abundant nutrient material the germ tube loses its power to react to contact stimuli, and the formation of appressoria is inhibited. If this were not the case, the mycelium would react to the contact of every obstacle, such as cell walls or starch grains, which it met in its course through the tissues, and growth would thus be made practically impossible. This is illustrated by the behavior of spores in weak beet infusion. Here the germ tube shows a tendency to form an appressorium, but before this is well formed it grows out again into a mycelial hypha, which immediately repeats the process. In old agar cultures which have been exhausted, the hyphae form a series of thick-walled cells of the nature of appressoria. These do not have the normal shape, but assume fantastically lobed forms, so closely crowded that they resemble sclerotia-like masses. The exhaustion of the nutrient material in the agar and the contact with the glass or other solid particles no doubt leads to the formation of these masses.

GERMINATION OF THE APPRESSORIA.

The appressoria germinate readily on a slide when covered with nutrient solution. The germ tube always emerges from the pore

on the surface appressed to the glass. By its vigorous growth it tilts the body to one side (*fig. 2*).

The process of penetration was observed by sowing spores on berries of *Berberis Thunbergii*, which are readily infected by the fungus, although some other species seem to be immune. From the pore on the lower flattened side of the adhesion disc, a slender tube protrudes and dissolves an arrow channel in the wax covering the cuticle. Although at first very slender, the hypha soon becomes larger and dissolves large cavities in the wax (*figs. 3, 4*). The fact that these cavities are more extensive than is necessary for the accommodation of the germ tube would seem to indicate that a solvent is secreted in sufficient quantities to accumulate on the outside of the infecting hypha. Finally the cell wall is perforated and the mycelium branches freely within the cells, at the same time sending hyphae into the neighboring cells. The penetration of the germ tube through the cuticle of the apple has frequently been observed, although it has not been possible to follow the mycelium farther, probably

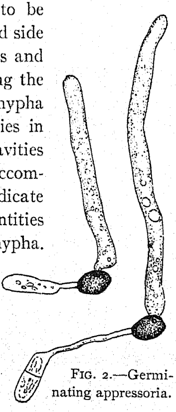


FIG. 2.—Germinating appressoria.

on account of the early collapse of the cells and the consequent

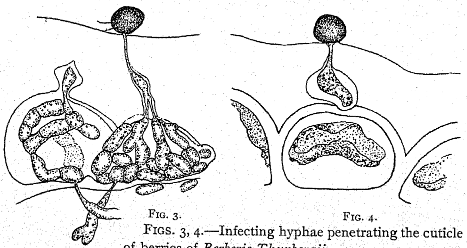


FIG. 3. FIG. 4.

FIGS. 3, 4.—Infecting hyphae penetrating the cuticle of berries of *Berberis Thunbergii*.

accumulation of débris. The channel in this case is very narrow but well defined. Contrary to former supposition no previous injury

or puncture of the fruit is necessary. This is further demonstrated by the number of infections occurring in apples. In some cases 100 to 200 infections were found on single apples, and recently SCOTT[13] reports the enormous number of 1,000 to 1,200 infections on single fruits. It is not likely that these represent previous mechanical injury to the fruits.

APPRESSORIA IN RELATION TO DISSEMINATION.

The behavior of the appressoria of the bitter-rot fungus under natural conditions is of interest from a biological standpoint. The spores of this fungus are imbedded in a gelatinous substance, which causes them to stick together in waxy masses when dry. By reason of this condition the spores cannot be distributed by wind. So far as known they are entirely dependent for their dissemination upon rain, although it is probable that insects take an active part in carrying the spores from tree to tree. Each season the first general infection of apples by the bitter rot is due to rain washing the spores from the limb cankers, in which the fungus hibernates, to the apples below. This is plainly shown by the observation that on a tree the infected apples are distributed within an area that can be circumscribed by a cone having its apex at the canker, the source of infection. Furthermore, drops of rainwater, collected from badly infected trees, usually contain numerous spores of the bitter-rot fungus.

Since the rain, at least in many cases, is the chief factor in distributing the bitter-rot spores, it is of interest to determine the effect of wetting and drying on the spores, and also the relative vitality of the spores and the appressoria. It should be stated, that while the spores are imbedded in their mucilaginous covering, they retain their vitality for a long time, but not during the entire winter, as has often been reported. In the latitude of Southern Illinois, spores remaining on apples under the trees either germinate[14] or perish long before spring. Spores taken from time to time from a diseased apple, which was kept dry in the laboratory from August until January, showed a large percentage of germination as late as Nov. 29, but later rapidly lost their vitality.

[13] SCOTT, W. M., The control of apple bitter rot. U. S. Dept. Agr. Bur. Pl. Industry Bull. 93. *pls. 8.* 1906.

[14] See also CLINTON, *l. c.*

To test the resistance of spores to drying after being freed from the surrounding mucilage by washing, a quantity of spores was shaken up with water and then spread out on glass slides which were allowed to dry. After remaining dry 14 hours, few spores germinated when again placed in water; after 24 hours, none germinated. At different times during the summer spores were shaken up in water and sprayed on filter paper, apples, and glass slides, but it was impossible to cause them to germinate after having been dried 24–30 hours.

That the appressoria are more resistant is shown by the following experiment. Appressoria were produced by sowing spores in drops of water on slides which were kept in a moist chamber until the following day. The slides were then allowed to dry, all the submerged spores having produced appressoria. The germination of the appressoria was tested from time to time by covering a slide with sugar-beet infusion. The appressoria germinated, though irregularly, as late as Dec. 11, when the last slide was used.

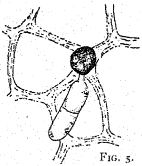


FIG. 5.

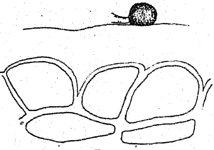


FIG. 7.

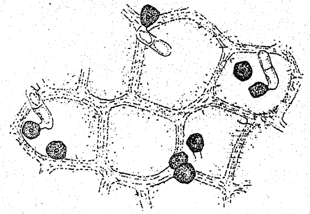


FIG. 6.

FIGS. 5, 6.—Natural appressoria formed on the surface of apples.

FIG. 7.—Section showing relation of adhesion organ to cuticle of apple.

During the hot summer weather the bitter-rot spores germinate immediately, and in 12–24 hours the appressoria are formed. Under natural conditions the germ tube is extremely short, since it immediately proceeds to the formation of an adhesion-disc. From this firmly adherent and more resistant organ the infecting hypha dissolves its way into the fruit. In badly infected trees the appressoria can often be found in great numbers adhering to the surface of the

apples. Such naturally formed appressoria are shown in *figs. 5, 6*, while in *fig. 7* a single adhesion organ is shown in section.

CONCLUSIONS.

The spore-like organs formed by the germ tubes of the anthracnoses are adhesion organs, by means of which the fungus is attached to the surface of its host during the early stages of infection. They are not suited for dissemination and therefore are not to be regarded as spores. The adhesion discs are formed as a result of stimuli from mechanical contact acting on the germ tubes. When growing in nutrient media the germ tubes lose their power of reacting to contact stimuli by the formation of appressoria. Under natural conditions the appressoria are formed as soon as the germ tube emerges from the spore.

NOTE.—In the same year ATKINSON describes these bodies for a species of Colletotrichum (*C. Gossypii*)[15] and suggests that their production in unfavorable conditions seems to favor the notion that they are resting bodies.

[15] ATKINSON, G. F., Anthracnoses of cotton. Journ. Mycol. **6**:173–8. *pls. 2.* 1891.

THE UNIVERSITY OF CHICAGO.

BRIEFER ARTICLES.

NEREOCYSTIS LUETKEANA.

(WITH ONE FIGURE)

This giant kelp is one of the most common, and certainly one of the most striking algae of the shores of northwest America. Its cylindrical, hollow stalks, as much as 21^{m} long, gradually widening from a diameter of 1^{cm} below to 10^{cm} above, surmounted by a bulb as much as 20^{cm} in diameter and provided with a crown of leaf-like fronds $3-9^{m}$ long; its habitat on submerged rocks over which it forms brown patches acres in extent, a warning to fishermen and pilots, and so dense that only with great difficulty can one get a rowboat through them; its presence everywhere in still waters and stranded along shores, torn loose and transported by waves and wind, attract the attention of every casual traveler along north Pacific shores. Two things concerning this plant at once impress the botanist, viz.: its remarkably rapid growth and its manner of solving the problems of life.

1. *Growth.*—We have here a plant $15-21^{m}$ long,[1] reported to reach a length of over 90^{m},[2] but probably erroneously; MACMILLAN[3] mentions 80 feet. HARVEY[4] states that it is growing at all seasons; fishermen and pilots, however, say that it disappears in winter. I knew the June condition of these plants, and I had accurately located several beds of them near the Marine Station of the University of Washington at Friday Harbor, Wash., during the summers of 1904 and 1905. On March 10, 1906, I made another trip to these beds with a view to determining whether or not this gigantic plant is an annual. The fishermen are partly right. Except for stragglers here and there, the kelps are gone; while those remaining were nearly all decayed and loose, with their fronds mostly torn away. Where the plants were floating freely, the remaining ones were yet in fair condition as to decay, as salt water prevents rapid bacterial action; but it required considerable searching to find a dozen good specimens.

Drifting over the reefs one can see, through a glass-bottomed bucket, on the bottom 3 to 9^{m} below, young plants of Nereocystis 1.25 to 2.5^{m}

[1] SAUNDERS, Algae of Harriman Alaska Expedition. Proc. Wash. Acad. Sci. **3**:431.

[2] ENGLER & PRANTL, Die natürlichen Pflanzenfamilien 1^{2}:259.

[3] Bull. Torr. Bot. Club **26**:273–299. 1899.

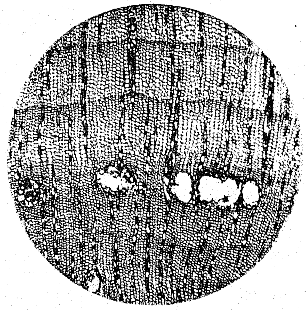
[4] Sea mosses 87.

long, with bulbs 12 to 38^{mm} in diameter, and fronds 30 to 90^{cm} long. It seems that they do not reach the surface the first year, but remain out of reach of waves, pushing rapidly up in the second season only to die when winter overtakes them. A growth of about 18^{m} in the second year, between the middle of March and the first of June, a period of about 70 days, requires on the average a growth of over 25^{cm} a day. The probability is that it is even greater, for March is cool on Puget Sound, so the growth would occur chiefly in the latter part of this period. In proof of this

FIG. 1.—*Nereocystis Luetkeana.*

belief is the fact that the ground was frozen during the whole week succeeding the time of observation; in fact, it was the coldest weather of the whole winter. Then too, another trip on May 10, 1906, but to a different bed, revealed none over 6^{m} long; so it is evident that they had 9 to 15^{m} of stretching before them for the next month. Twenty-five centimeters per day is about 0.175^{mm} per minute, which is between one-third and one-fourth as rapid as that reported for the bamboo,[5] and far above that of ordinary plants. One hardly expects prolonged rapid growth in the latitude of Puget Sound, but Nereocystis certainly furnishes an example of it.

[5] STRASBURGER *et. al.*, A text book of botany, English edition, 231. 1903.



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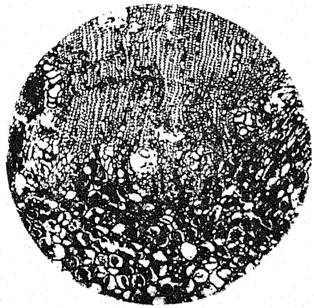

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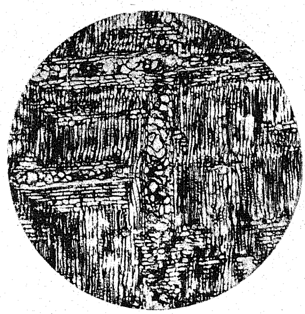

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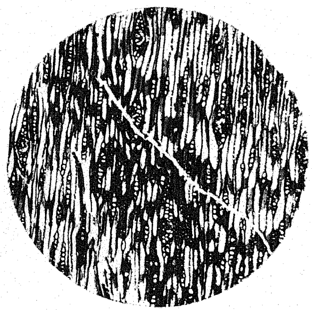

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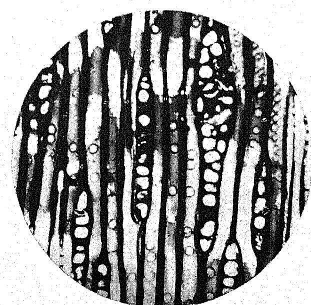

6

JEFFREY & CHRYSLER on PITYOXYLA

2. *Life relation.*—The shore just below low tide to a depth of 6^m is taken up by shorter, broad algae, mostly brown, many green, a few red; limited up shore by the grinding wave-washed rocks as the tide level varies, and by the baking heat of a summer sun during low spring-tides; limited downwards by the decreasing sunlight; we find on this strip the battle ground of the green and brown algae, species against species. Nereocystis, with its tough, flexible, cattle-whip-like stalk 12 to 21^m long, rises from the bottom in the deeper waters, a veritable Esau, surrendering to the Jacobs the coveted strip and wresting from the undesired, comparatively unoccupied territory beyond, a highly successful existence. The stalk is firmly anchored to the rocks below by holdfasts covering an area as much as 30^{cm} in diameter. So strong and tough is the stalk, and so firm the attachment, that often a pull of several hundred pounds is necessary to loosen the plant; and then the stalk more often than the holdfast gives way; but a large plant, avoiding quiet waters, needs a firm hold, and one occasionally finds the plants washed ashore with holdfasts dragging rocks as much as 20^{cm} in diameter. The admonition to "build upon a rock" holds for Nereocystis, and the rock must be a big one; those which "build upon sand" are washed away before they reach the adult stage. This is one of the reasons why it grows upon reefs.

Algae love moving water, but few can afford it. Moving water facilitates gas exchange by carrying away that ladened with evolved and lacking in desired gases, and by not depositing suspended materials like quiet water. A layer of beach washings over a plant absorbs sunlight, one of the scarcer commodities of marine algae, any diminution of which only those most favorably located can afford. Nereocystis, by its firm anchorage and long stalks, surmounted by a bunch of tough blades 3 to 9^m long but narrow for their length, rides easily in flowing water, and chooses for its home the rocky, clean-swept, tide-washed promontories, where the current keeps its blades horizontal.

Below 6^m the brown algae rapidly decrease, and dredging in Puget Sound shows that below 12^m they are exceptional. They need light. It is well known too, that the decrease in light downward in water is rapid. This makes the surface the most desirable location. But shore forms, at the surface at high tide, are stranded high and dry at low tide; and those at the surface at low tide are covered at high tide, the depth depending upon the difference between high and low tide. This constant change in water level is one of the greatest difficulties with which seaweeds have to contend. We see at once that marine algae have a very serious problem, to steer clear of the Scylla of darkness on the one hand, and, on the other,

at a very short bow-shot's distance, the Charybdis of tide-line destruction by wave and sun. Nereocystis has solved the problem by the floating dock. Its holdfast at the smaller end of the stalk serves as the anchor, fastened far enough off shore to prevent stranding at low tide; its hollow bulb, surmounting the larger, hollow end of the stalk is the float; attached to the bulb are the leaves, constantly at the surface, supple, tough, safe in storm, current, and varying tide. However, it has minor troubles, since in creating for its own fronds an excellent environment it has created also an excellent habitat for other forms as well. It is not uncommon to see the bulbs and stalks densely covered with delicate red and green algae, and hydroids and bryozoa. Rising from unoccupied territory, and creating for its fronds one of the best habitats among marine algae, *Nereocystis Luetkeana* challenges the respect of the botanist and the lover of nature.—THEODORE C. FRYE, *State University, Seattle, Washington.*

TWO NEW SPECIES FROM NORTHWESTERN AMERICA.

MISS EDITH M. FARR of Philadelphia has recently submitted to the writer a small collection of plants for identification. The collection was made in the mountainous regions of Alberta and British Columbia, chiefly in the vicinity of Banff, Lake Louise, Field, etc., during the summers of 1904 and 1905. Among other interesting rarities there are two which the writer has been unable to place satisfactorily in any described species. These are characterized as follows:

Castilleja purpurascens Greenman, n. sp.—Perennial, more or less purplish throughout: stems erect or nearly so, 1 to 3^{dm} high, usually several from a multicipital caudex, glabrous or puberulent below, villous above: leaves sessile, subamplexicaul, linear to narrowly lanceolate, 1.5 to 4.5^{cm} long, 1 to 7^{mm} broad, usually attenuate and acute, entire and undivided or occasionally 3-cleft near the apex, glabrous or the upper somewhat villous-pubescent, 3-nerved; the lowermost leaves much reduced: inflorescence terminating the stem in a subcapitate raceme, later elongating to about 7^{cm} in length, villous-pubescent; bracts ovate-lanceolate to oblong-ovate, 2 to 2.5^{cm} long, usually entire, occasionally cleft: calyx 1.5 to 2.5^{cm} long, and as well as the bracts varying in color from a deep purplish-red to scarlet and rarely to yellow tinged with red or pink, about equally divided before and behind, externally villous with glandular hairs intermixed; the lateral divisions 2-lobed, lobes obtuse: corolla 2 to 3^{cm} long; galea about one-half as long as the corolla-tube, green or greenish-yellow the glandular puberulent back, with scarlet or magenta colored

margins, conspicuously exserted beyond the calyx and floral bracts; lip usually dark green, 3-lobed, about one-fourth the length of the galea, commonly protruding through the anterior fissure of the calyx: mature capsule oblong, 7 to 8^{mm} long, abruptly acuminate or subapiculate, strongly compressed laterally, glabrous: seeds about 1.5^{mm} long, yellowish-brown.

BRITISH COLUMBIA: near Field, at an altitude of about 1200^{m}, 7 June, 1905, Miss *Edith M. Farr*, nos. 567, 568 (type), 569, 570, 571, 572, 573, 574 (form with yellowish inflorescence slightly tinged with red or pink), 575, 576. Type in hb. Field Museum and hb. Univ. of Penn.

The suite of specimens here cited shows considerable variation in color and to some extent variation in foliage, but all have the same habit and technical characters of the flower. The species apparently has its nearest affinity with *Castilleja Elmeri* Fernald, from which it differs in being glabrous or essentially so below, in having a more slender inflorescence, narrower floral bracts, and a more conspicuously exserted corolla with a somewhat longer galea. The purplish cast of the entire plant with the galea extending well beyond the crimson or purplish bracts and calyx renders this an attractive species and easily distinguished among its numerous allies.

Senecio (§AUREI) **Farriae** Greenman, n. sp.—An herbaceous perennial 1 to 1.5^{dm} high: stem erect or ascending, branching from near the base, glabrous except for a persistent white tomentum in the leaf axils; branches few, relatively long and terminated by a single head: basal leaves ovate to slightly obovate, the blade 1 to 3^{cm} long, 1 to 1.5^{cm} broad, rounded at the apex, crenate-serrate to subentire, contracted at the base into a narrowly winged petiole equaling or exceeding the blade, glabrous or nearly so; the lower stem leaves sublyrate or more or less irregularly pinnatifid, the upper reduced to entire bracts: heads about 1^{cm} high, radiate: involucre campanulate, slightly calyculate, tomentulose at the base; bracts of the involucre usually 21, linear-lanceolate, about 8^{mm} long, nearly or quite equaling the flowers of the disk, acute, reddish tipped: ray-flowers 12 to 14; rays orange-yellow; disk-flowers numerous.

ALBERTA: near Banff, altitude 1500^{m}, 8 June, 1904, Miss *Edith M. Farr*. Type in hb. Univ. of Penn., fragment and photograph in hb. Field Museum.— J. M. GREENMAN, *Field Museum of Natural History, Chicago*.

CURRENT LITERATURE.

BOOK REVIEWS.

Plant response.

No SUBJECT is more fascinating than the responses of plants to stimuli; and though the mechanisms involved are often much simpler than in the case of animals, no subject is more difficult. Papers dealing with limited topics in this field are constantly appearing; one feels some surprise at seeing a large volume of new researches dealing with the matter in the most fundamental fashion. The surprise is increased when it is seen that the author is one whose name is new in the literature of plant physiology and whose nation is fond rather of speculative philosophy than of scientific observation. Professor JAGADIS CHUNDER BOSE of Presidency College, Calcutta, published in 1902 a volume on *Response in the living and non-living*, in which he pointed out many parallels between the "irritability" of organisms and of other bodies. But this volume seems not to have attracted general attention among physiologists; and some of those who read it were inclined to discount the parallelism as one suggested rather by philosophic bias than scientific induction.

On opening this new work[1] the plant physiologist will be inclined to think it some volume on muscle-response in animals, the numerous graphs being quite like those made familiar by the usual records from muscle-nerve apparatus. Closer inspection, however, shows that the author, trained in a laboratory for animal physiology and in the methods of research in vogue for pulse and muscle, has applied these methods to detecting before unsuspected (or at least unrecorded) responses in plants.

But he has done much more than merely apply the existing apparatus and methods. He has employed new methods and has devised new and ingenious apparatus for automatically recording responses. For example, there are described many clever minor adaptations of the optic lever and various electric devices; and among the major ones may be enumerated the kunchangraph (Sanskrit: *kunchan*=contraction) for recording longitudinal contraction in radial organs on applying electric, thermic, or chemic stimuli; the morograph, for recording the death spasm of the contractile protoplasm, and the comparison morograph for recording the response of two plants simultaneously while under different conditions; the shoshungraph (Sanskrit: *shoshun*=suction) for recording the rate of transpiratory suction and its variations; the crescograph,

[1] BOSE, J. G., Plant response as a means of physiological investigation. 8vo. pp. 781. *figs. 278.* London, New York, and Bombay: Longmans, Green, & Co. 1906.

balanced so as to record the average rate of growth as a straight horizontal line, any fluctuation, even the slightest, showing as deviation from this horizontal line; and the magnetically controlled heliotropic recorder, utilizing the optic lever yet avoiding the use of light within the plant chamber, except that which is the stimulus.

One striking feature of all the apparatus, aside from its ingenuity, is the high magnification which it permits. This is at once an advantage and a danger; but consistent results, if critically controlled, ought to guard against serious error.

The book is not without errors, both of reasoning and fact, into which the author has fallen by reason of some unfamiliarity with his materials. No one could justify himself in accepting as established all the deductions from the vast number of experiments detailed in the book; they must be verified sooner or later by other observers. To our knowledge some have already been repeated (some of those, for instance, on the variation in electric potential resulting from stimulation, in Dr. HARPER's laboratory at the University of Wisconsin) with concordant results. But whatever the future may show as to the accuracy of details, this book may be acclaimed as a path-breaking one; for it shows a method of attack and a refinement of instrumentation for the study of the phenomena of irritable reactions in plants that are sure to be of the utmost service. It is rather remarkable, indeed, that we have had so few recording instruments in the service of plant physiology, and that we have been content, for example, with magnifications of 10 or 20 times in the auxanometer, where BOSE finds 1,000 or even 10,000 practicable with his crescograph.

The fundamental thesis of the book is that the underlying response to stimuli is alike in plants and animals; is alike in all plants and in all parts, with all stimuli; and is universal. This response, however diverse its modes of expression, consists of two very simple and well-defined factors, contraction and expansion; the former the direct effect of stimulation, the latter the indirect. Mechanical response is always by a concavity of the more excited side and may or may not occur; electrical response can always be detected; growth is merely a multiple response; at death (near 60° C. for phanerogams) a sudden and irreversible molecular change takes place, attended by an excitatory contraction. The phenomena of fatigue, of staircase response when the organ is at first sluggish, of tetanus, of the polar effects of electric currents, of variation in electric potential, of transmission of stimuli, and of rhythmic responses—all can be demonstrated in plants as in animals, giving evidence in greater detail of the essential unity. With this BOSE is more impressed and on it he lays more stress than the case demands; for it is by no means so novel an idea to botanists as to most zoologists.

Of all the fifty chapters in the book none are so unsatisfactory as those on the ascent of sap, constituting part V. BOSE holds that he has demonstrated the ascent of water to be due to the physiological activity of living cells whose suctional response is coordinated by the passage from point to point of an exci-

tatory reaction which drives water in one direction.[2] But some of his reasoning is radically defective, the chapters are full of assumptions, and his experiments are inconclusive. Indeed, he hardly seems to know how difficult a problem he is attacking, and he goes at it with the naïveté of a novice. Such work really tends to prejudice one against the whole book; and caution *is* necessary, for there are other weak spots. In spite of these, the suggestiveness, the ingenuity, and the enormous labor displayed impel us to give this book a most cordial reception. And we shall await with much interest a promised volume on the electrophysiology of plants.—C. R. B.

MINOR NOTICES.

N. Am. Uredineae.—The second part of HOLWAY'S photomicrographs of plant rusts[3] has just appeared, having been delayed several months by a printer's strike. The general character and purpose of this publication were described in this journal[4] upon the appearance of the first part. The present part continues the genus Puccinia through eleven host families, ending with Rosaceae. The photogravure plates carry out fully the promise of the first part.—J. M. C.

Schneider's Handbuch.—The fifth part of the *Illustriertes Handbuch der Laubholzkunde*[5] concludes Drupaceae and includes Pomaceae, and ends the first volume. There are 128 text figures, and a volume index of genera.—J. M. C.

NOTES FOR STUDENTS.

The ascent of water.—After GODLEWSKI'S interesting theory of the relay-pump action of the medullary rays in lifting water seemed to have been completely overthrown by STRASBURGER,[6] who found water still ascending for weeks after treatment calculated to kill living cells, the participation of living cells in lifting water found a champion on theoretical grounds in SCHWENDENER.[7] But PFEFFER[8] hardly dared more than to suggest that they might be of importance in

[2] See in this connection reviews of other recent papers below.

[3] HOLWAY, E. W. D., North American Uredineae, Vol. I. part II. 4to. pp. 33–56. *pls. 11–23*. Minneapolis, 1906. $2.00.

[4] BOT. GAZETTE 40:459. 1905.

[5] SCHNEIDER, CAMILLO KARL, Illustriertes Handbuch der Laubholzkunde. Fünfte Lieferung. Jena: Gustav Fischer. 1906. *M* 4.

[6] STRASBURGER, E., Ueber den Bau und die Verrichtungen der Leitungsbahnen in den Pflanzen. Histologische Beiträge 3. Jena, 1891. Ueber das Saftsteigen. Histologische Beiträge 5. Jena, 1893.

[7] SCHWENDENER, S., Zur Kritik der neuesten Untersuchungen über das Saftsteigen. Sitzb. Berliner Akad. 44:911–946. 1892. Gesammelte Unters. 1:256–297. Weitere Ausführungen über die durch Saugung bewirkte Wasserbewegung in der Jamin'schen Ketten. Sitzb. Berliner Akad. 45:835–846. 1893. Gesammelte Unters. 1:298–315. 1898.

[8] PFEFFER, W., Pflanzenphysiologie 1:203. 1897.

the maintenance of normal conditions in the conducting tissues. Then URSPRUNG rallied to the support of SCHWENDENER with experimental work, and in a paper published two years ago[9] contended that the living cells, either by maintaining the conducting system in condition or by actually lifting, had an important share in the ascent of water. His experiments were carried out on small plants mainly, and he ventured no generalization.

In a more recent paper[10] he reviews critically the direct and incidental experiments of others on this subject, replies to objections raised against his earlier paper; and details further experiments intended to ascertain the precise rôle of living cells. The author adopts a rather hypercritical attitude toward previous results, as is well illustrated by this reasoning regarding girdling: "If at the base girdling 1^{dm} long is borne without injury, it does not signify that this would be the case also at the apex; and if girdling 1^{dm} long does not interrupt the conduction of water, it is not proved that this would not occur with girdling one or two meters long. Hence it follows that the bark (*Rinde*) must be entirely removed if one wishes to form a judgment as to its share in the ascent of sap; and even then one can at most only recognize that it may be dispensed with—not that under ordinary conditions it takes no part in the ascent of sap."

By liberal discounts URSPRUNG arrives at the conclusion that *all* previous researches on this point speak in favor of the participation of living cells in raising water. Even the experiments of STRASBURGER, which have been interpreted as flatly contradictory to such an idea, are counted as offset by his finding that the leaves die after one actually kills 10^{cm} of the stem. For, according to URSPRUNG, the cooperation of living cells throughout the entire length of the plant is necessary; but a small fraction of the conducting system suffices to supply water if in this region the wood cells are living; whereas the whole is inadequate to furnish enough water when they are killed. These living cells do not merely keep the conducting tissues in good condition; they "cooperate in the production of the lifting force," and the component which they furnish is of great significance in comparison with the "purely physical." A notable exception is the beech, in whose older parts the cells of the bark are without influence, "and even in the youngest parts such interaction is insignificant." It is hard to conceive how the living cells in the bark, being outside the water paths, can participate in the work of raising water, and harder still to imagine that they do so in certain plants and not in others.

STEINBRINCK attacks the problem from the "purely physical" side,[11] and

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9 URSPRUNG, A., Untersuchungen über die Beteiligung lebender Zellen am Saftsteigen. Beihefte Bot. Cent. **18**:145–158. 1904.

10 ———, Die Beteiligung lebender Zellen am Saftsteigen. Jahrb. Wiss. Bot. **42**:503–544. 1906.

11 STEINBRINCK, C. Untersuchung über die Kohäsion strömender Flussigkeiten mit Beziehung auf das Saftsteigeproblem der Bäume. Jahrb. Wiss. Bot. **42**:579–625. 1906.

seeks to extend our knowledge of hydrodynamics. He examined the cohesion of water by means of the supersiphon, i. e., a siphon whose legs are so long as to permit the use of columns of liquid too high to be raised by atmospheric pressure, to which (STEINBRINCK thinks erroneously[12]) the action of the common siphon is ascribed. He attempted to ascertain the cohesion of water under various conditions, and met sometimes with such capricious behavior of his apparatus that, more than ever by this experience, he is convinced of the necessity for much more extended physical knowledge before the problem of the ascent of sap can be solved. The reinvestigation of the tension of gases in fern and other sporangia (which he finds nearly at atmospheric pressure) and of their disappearance when the sporangia are wetted, shows that these phenomena do not fall in with any known physical laws; and as these structures plainly contain only dead cells the problem cannot be obscured by dragging in "vital activities" and remains at present inexplicable. How much more caution, then, is needed in the more complex problem of sap movement!

STEINBRINCK finds that a water filament 2^{mm} thick, moving at the rate of 2^{cm} per second, bears a pull of four atmospheres, its tensile strength increasing with diminishing size and rate of flow. Such filaments bear even violent shaking, under certain conditions, without rupture. Their stability is not affected by extremes of temperature that would be encountered in the growing season (say $0°$ to $35°$ C.). By ingenious experiments he shows that cohesion may act through membranes, such as the partitions that interrupt the tracheae. As for the objection to the cohesion theory on account of the Jamin-chain condition, he suggests caution on account of deficient physical knowledge, enforcing this by citing the case of gas absorption in the opening sporangia already alluded to. He does not deny the participation of living cells, but can form no conception of the manner in which they act.

EWART, recognizing that water is a liquid of definite viscosity and that the channels through which it moves are small, thereby offering great resistance, has endeavored to ascertain the amount of this resistance in definite cases, and the possible means by which is generated the force necessary to raise water at the required rate.[13] He finds that the flow of water through open vessels is in accord with POISEUILLE's formula deduced from flow through rigid tubes; hence the velocity is proportional to the pressure and to the square of the radius of the tube, and inversely proportional to the length of tube and viscosity of the liquid. The total resistance in erect stems corresponds to a head of water 6 to 33 (for shrubs and small trees) or 5 to 7 (for large trees) times the height of the plant. Hence, in the tallest trees, the pressure required may be as much as 100 atmospheres. The maximal osmotic suction of leaves in an elm 18^{m} high was 2–3

[12] STEINBRINCK, C. Ueber dynamische Wirkung innere Spannungsdifferenzen etc. Flora **93**:127–254. 1904.

[13] EWART, A. J., The ascent of water in trees. Phil. Trans. Roy. Soc. London B. **198**:41–85. 1905.

atmospheres, with a total resistance to flow in the trunk of 10–12Å. "It appears, therefore," concludes EWART, "that to maintain flow, a pumping action of some kind or other must be exercised in the wood, for which the presence of active living cells is essential. . . . . There is no known means by which these cells can directly pump water in a definite direction. . . . . It is suggested that the wood parenchyma cells, by the excretion and reabsorption of dissolved materials, may bring into play surface tension forces within the vessels of sufficient aggregate intensity to maintain a steady upward flow, and to keep the water of the Jamin's chains in the vessel in a mobile condition, ready to flow to wherever suction is exercised."

But STEINBRINCK declares himself (*l. c.*) unable to form any conception of how such an action can be produced, and LARMOR objects[14] on purely mechanical grounds, saying: "If the osmotic gradient, assisted by capillary pull at the leaf orifices, is insufficient to direct a current of transpiration upward, *capillary* alterations inside the vessels, arising from vitally controlled emission and absorption of material from the walls cannot be invoked to assist." He suggests that *osmotic* changes in the vessels, of peristaltic character, might do; but he apparently does not know that osmotic phenomena do not occur in sap vessels. As a physicist, he inquires whether there is a sufficient stock of energy in the stems for the pumping work required; and he renews the eminently plausible suggestion that the work is done where the external energy is received, viz., in the leaves.

It cannot be said that these researches have solved the problem of water movement. But each in its own way has added something to our knowledge. The more hopeful lines seem to be in determining physical factors and studying more closely the dynamics of the question.—C. R. B.

Gymnosporangium galls.—The anatomical changes induced by *Gymnosporangium clavariaeforme* and *G. juniperinum* on the twigs and leaves of their host, *Juniperus communis*, have been investigated by LAMARLIÈRE[15] with the following main results. The mycelium of *G. clavariaeforme* inhabits the cortex and phloem regions, but does not penetrate into the wood. The cells of the cortex are multiplied and enlarged so that all lacunae are obliterated, resulting in a general hypertrophy of this region. The formation of collenchymatous tissue is almost entirely suppressed. In the phloem region the medullary rays undergo the most marked transformation. Not only do the rays themselves become more numerous, but the cells composing them are also greatly increased in number, so that this tissue is likely to make up about one-half the volume of the bast region. The sieve tubes, parenchyma, and bast fibers retain their normal succession, but owing to the great increase in parenchyma from the rays and from the increased volume of the bast parenchyma, the course of the sieve

[14] LARMOR, J., Note on the mechanics of the ascent of sap in trees. Proc. Roy. Soc. B. **76**:460–3. 1905.

[15] LAMARLIÈRE, L. GÉNEAU DE, Sur les mycocécidies des Gymnosporangium. Ann. Sc. Nat. Bot. IX. **2**:313–350. *pls. 8–12*. 1905.

tubes and bast fibers becomes distorted and irregular. The cambium ring also is broken and irregular from the fact that uniform differentiation into phloem and xylem no longer occurs. In the wood the medullary rays undergo transformation as in the phloem, becoming irregular masses of parenchymatous storage tissue. The wood is also considerably enlarged.

In *G. juniperinum* the changes are similar but less marked, the greatest changes in the medullary rays being near the periphery. The sieve tubes are mostly suppressed and the xylem is somewhat reduced. In the leaves the chief change induced by this fungus is the transformation of the spongy parenchyma into palisade-like tissue. The observations of this writer agree in detail with the more extensive account of WOERNLE, whose excellent paper on the anatomical changes induced by both the European and American species of Gymnosporangium is nowhere cited or referred to in the article.

As a general result of the effects of the fungus on its host, LAMARLIÈRE points out the tendency toward "parenchymatization," i. e., a tendency of the cells to remain in their more undifferentiated form, a phenomenon from which he draws a parallel to tuber formation.—H. HASSELBRING.

Dioecism among Mucorales.—In continuation of his studies of dioecism among the Mucorales, BLAKESLEE[16] has recently investigated the extent to which differentiation of sex occurs in the spores from germ-sporangia obtained from zygospores. The principal results contained in the paper are as follows. The germ-sporangia of the homothallic species *Sporodinia grandis* and *Mucor* I (undescribed) contain but a single kind of spores, which produce mycelia again capable of forming zygospores. With the heterothallic species the case is different. Here spores in the germ-sporangium may be either all (+) or all (−), or (+) and (−) may be mixed. Of the species tested, *Mucor mucedo* produces all (+) or all (−) spores in its germ-sporangia, showing that a segregation of sex takes place at some period previous to the formation of spores. In *Phycomyces nitens*, however, (+) and (−) spores are mixed in the same germ-sporangium, together with others that show a tendency to produce a homothallic strain. The mycelia of the homothallic strain are characterized by the production of irregular contorted growths to which the writer gives the name *pseudophores*. The production of sporangia on these mycelia is very limited. The spores from them show a segregation into (+) and (−), and others reproducing the homothallic strain.

The reading of this paper is made somewhat difficult partly through lack of clearness in style, which is as essential in scientific exposition as is accuracy in investigation, and partly through the loose use of terms introduced by the author himself. The terms heterothallic and homothallic as used in the earlier papers on zygospore-formation apply to the condition of sexual differentiation of the individuals within a species, strain, or form, being equivalent to dioecious and monoecious. While it is possible to speak of a heterothallic species or race, it

[16] BLAKESLEE, A. F., Zygospore germinations in the Mucorineae. Annales Mycol. 4:1–28. 1906.

is difficult to see how this conception can be applied to individual mycelia or to spores, or even to the process of germination, as is done repeatedly by the author. Perhaps the introduction of new terms is superfluous in this case, for the idea is well expressed by the older terms dioecious and monoecious. These are used in reference to algae, where the condition thus designated exists.—H. HASSELBRING.

Fixation of nitrogen.—The Agricultural Research Association, a Scottish society which has its station at Glasterberry near Aberdeen, has published in its Report for 1905 a paper by the Director of Research, THOMAS JAMIESON,[17] Chev. Fr., F. I. C., which is supposed to overthrow the current knowledge as to the fixation of nitrogen by the root tubercle organisms and to prove that plants of many sorts utilize the nitrogen of the air directly by means of the hairs with which the leaves are furnished. The laudations with which this pretended "research" was received at the annual meeting by men even more ignorant of the subject than the "director of research," are really worthy of a place in comic literature, were it not for its serious side in giving local currency at least to foolish notions.

The "research" itself is its own condemnation, and shows the "director" to be as ignorant of chemistry as of the physiology and anatomy of plants. Here is a serious society in Scotland, spending money for that which is not bread, lauding an imposture as a wonderful discovery, publishing a report with twelve colored plates illustrating the "albumen generators" imagined by a man who does not know the difference between surface hairs and the spiral tracheae of "Holly laurifolia"! Further it summarizes the previous "leading results" of this same "director;" among which we note the discovery that there is "an aperture in root hairs by which the absorption of insoluble matter is explained;" and that the "feathery structures in the flowers of cereals and grasses are not essential parts of the pistil but serve to drive out the anthers to the air"!

Yet we can hardly bring a railing accusation against the misled members of this society when our own postoffice department has had recently to deny the use of the mails, to prevent our own people from being swindled, to a rascal who is advertising "vineless potatoes," that produce a large crop of tubers when planted in wet sawdust and watered with "potatine" at $4.50 per! Truly, some botanical training might save the farmer from his foolish as well as his knavish friends.—C. R. B.

Corky cell-layers in monocotyledons.—MÜLLER describes[18] in detail the cutinized membranes in the root and stem of *Convallaria majalis*, viz., epiblem covering the root-cap, intercutis of greater or less thickness in the cortex of root

[17] JAMIESON, THOMAS, Report for 1905 to Agricultural Research Association. 8vo. pp. 81. 1905.

[18] MÜLLER, HEINRICH, Ueber die Metacutisierung der Wurzelspitze und über die verkorkten Scheiden in den Aehren der Monocotyledonen. Bot. Zeit. **64**:53–84. *pl. 3.* 1906.

and rhizome, endodermis, and epidermis. The microchemical reactions for each of these layers are given. A process called "metacutinization" is described, which involves all the outer cells of a root-tip, and occurs at the end of the growing season. Four stages in the development of the endodermis are distinguished, following KROEMER, viz., embryonic, primary (characterized by presence of CASPARY'S points), secondary, and tertiary (showing suberization and lignification of a large part of the wall). The endodermis of the root does not usually pass through more than the first two stages. The writer brings together the information available concerning the presence or absence of an endodermis in monocotyledonous stems, and a survey of the tables shows that in about 60 per cent of the species an endodermis is present in the underground stem, while only in Medeola and Scindapsis has an endodermis been reported for the aerial stem. The relation of the starch sheath of aerial stems to the endodermis of rhizomes was also studied, and the writer failed to establish an actual continuity between the two layers. The function of the endodermis is said to be the transfer of water and food between the central cylinder and the cortex, and the increasing cutinization is associated with the necessity for checking the movement of solutes in the radial direction.—M. A. CHRYSLER.

Items of taxonomic interest.—H. D. HOUSE (Muhlenbergia **1**:127–131. 1906) publishes several changes in the nomenclature of Orchidaceae, and describes a new Californian species of Dichondra.—A. A. HELLER (*idem* 134) publishes a new Californian species of Ribes.—Under the editorship of IGN. URBAN (Engler's Bot. Jahrb. **37**:373–462. *pl. 9.* 1906) a fascicle of 18 contributions describing new Andean plants has been published, among which the following new genera appear: *Orchidotypus* (Orchidaceae), by F. KRÄNZLIN; *Laccopetalum* (Ranunculaceae), by E. ULBRICH; *Belonanthus* and *Stangea* (Valerianaceae), by P. GRAEBNER, who gives a general synopsis of the family.—R. PILGER (idem, Beiblatt 85, pp. 58–67) describes a new genus (*Lamprothyrsus*) of South American grasses near Danthonia.—S. LEM. MOORE (Jour. Botany **44**:145–154. 1906) has described 2 new genera from Madagascar: *Cloiselia* (Compositae) and *Stenandriopsis* (Acanthaceae).—R. M. HARPER (Bull. Torr. Bot. Club **33**:229–245. 1906) has described new species from the coastal plain of Georgia under Sporobolus and Nymphaea.—W. H. BLANCHARD (Rhodora **8**:95–98. 1906) has described two new species of Rubus from New England, both of them high blackberries.—A. ZAHLBRUCKNER (Ber. Deutsch. Bot. Gesell. **24**:141–146. *pl. 10.* 1906) has described a new genus (*Lindauopsis*) of parasites in the hymenium of lichens.—R. SCHLECHTER (Bot. Jahrb. **39**:161–274. *figs. 13–23.* 1906), in completing his account of New Caledonian plants, describes the following new genera: *Menepetalum* (Celastraceae), *Acropogon* (Sterculiaceae), *Memecylantus* and *Pachydiscus* (Caprifoliaceae).—J. M. C.

Double fertilization in Carpinus.—In 1893 Miss BENSON published her first paper on the embryology of the Amentiferae. This is now followed by a second

paper,[19] dealing especially with the behavior of the pollen tube in connection with double fertilization in *Carpinus Betula.* As the previous paper pointed out, this form is chalazogamic, and usually has several embryo sacs, which develop caeca that penetrate deeply into the chalazal region. The course of the pollen tube varies considerably, but usually it enters the embryo sac at the base of the caecum. Premature arrival of a pollen tube results in more or less branching and coiling about the sacs; and belated pollen tubes also occur, long after fertilization has been accomplished. The polar fusion nucleus is in the caecum, and as the pollen tube passes it one of the male cells (probably the one farthest from the tip) is discharged through a small spur-branch, the other one being discharged upon the arrival of the tip in proximity to the egg. Sometimes the spur-branch, containing a male cell, develops sufficiently to discharge it for the fertilization of the egg of an adjacent embryo sac, in this case triple fusion not occurring. The paper also presents a somewhat elaborate comparison of Carpinus and Casuarina, as the basis of a suggestion that the latter genus should be regarded as a subfamily of Betulaceae.—J. M. C.

Dust spray vs. liquid.—CRANDALL[20] reports the results of a very thorough study of the comparative merits of the dust spray and the ordinary liquid Bordeaux mixture against the scab and sooty blotch of apple and the codling moth and curculio of apple. The dust spray cost about 52 per cent less than the liquid spray and there was further gain in the reduced weight of material to be transported about in the orchard. On the contrary there seemed to be no difference in the thoroughness of application under similar conditions, and the workmen were unanimous in considering the liquid spray the least disagreeable one to apply. And then as to the final and most important test, that of efficiency, CRANDALL says, in conclusion, "The results of the experiments are sufficiently decisive to warrant the conclusion that dust spray is absolutely ineffective as a preventive of injury from prevailing orchard fungi, and that it is considerably less efficient as an insect remedy than is the liquid method of applying arsenites." —E. MEAD WILCOX.

Nature of starch.—In a recent article, FISCHER[21] scouts the idea suggested by CZAPEK[22] that starch may be a mixture of colloidal and crystalline materials, saying that so far as he knows there is not the slightest evidence for such a belief.

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[19] BENSON, MARGARET, SANDAY, ELIZABETH, and BERRIDGE, EMILY, Contributions to the embryology of the Amentiferae. Part II. *Carpinus Betula.* Trans. Linn. Soc. London Bot. II. 7:37–44. *pl. 6.* 1906.

[20] CRANDALL, C. S., Spraying apples. Relative merits of liquid and dust applications. Bull. Ill. Exp. Stat. 106:205–242. *pl. 1–9. figs. 1–5.* 1906.

[21] FISCHER, HUGO, Ueber die colloidale Natur des Stärkekörner und ihr Verhalten gegen Farbstoffe. Beihefte Bot. Cent. 181:409–432. 1905.

[22] CZAPEK, F., Biochemie der Pflanzen I. Jena 1904.

He does not refer to the work of KRAEMER[23] or of MAQUENNE and ROUX,[24] who independently and from very different standpoints have found evidence of such a mixture. Since starch shows seven characteristic colloidal properties and only two crystalline properties he concludes that it is a colloid.

The author discusses at length the theories of staining with anilin colors, dismisses as wrong the adsorption theory, and concludes that, while in some cases, as in the staining of proteids, the reaction may be largely chemical, in most cases the taking up of the color is by solution, dyes not soluble in water being soluble in starch. He further concludes that the solution is a liquid and not a solid solution, the colloidal starch in the swollen grains being in a liquid state.—EDNA D. DAY.

Heterospory in Sphenophyllum.—This genus has been regarded as strictly homosporous, but THODAY[25] now describes and figures a section through the strobilus of *S. Dawsoni* which shows two adjacent sporangia, one of them containing spores of uniform size, the other containing fewer and larger spores, among which are seen numerous very small aborted ones. These contrasting sporangia certainly suggest heterospory, but the largest of the supposed megaspores has only about 1.5 times the diameter of the spores of the other sporangium. It will be remembered that in *Calamostachys Casheana* the megaspores are only three times as large as the microspores, and this was felt to be a remarkably small difference.—J. M. C.

Proteid metabolism in the ripening barley grain.—The first section of a paper to consist of three has been presented by SCHJERNING.[26] A short notice to call the attention of physiologists is appropriate here, but the reliability of the methods and conclusions must remain unconsidered. The author finds that species, variety, or type *per se* do not affect the chemical composition of the dry matter of the grain so far as the nitrogenous and mineral constituents are concerned. As the grain develops to maturity there is a constant tendency toward equilibrium between the nitrogenous constituents, which is established at maturity and which is not disturbed during subsequent storage except in the case of certain albumins.—RAYMOND H. POND.

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23 KRAEMER, HENRY, The structure of the starch grain. BOT. GAZETTE. **34**: 341. 1902.

24 MAQUENNE et ROUX, Sur la constitution, la saccharification et la rétrogradation des empois de fécule. Comptes Rendus Acad. Sci. Paris **140**: 1303–1308. 1905.

25 THODAY, D., On a suggestion of heterospory in *Sphenophyllum Dawsoni*. New Phytol. **5**: 91–93. *figs. 14*. 1906.

26 SCHJERNING, H., On the protein substances of barley, in the grain itself and during the brewing processes: First section: On the formation and transformation of protein substances during the growth, ripening, and storage of barley. Compt.-Rend. Lab. Carlsberg **6**: 229–305. 1906.

Lolium-fungus and smut.—In a short paper FREEMAN[27] points out the probability of relationship between the fungus of *Lolium temulentum* and the smuts. Partly by reason of the facts discovered by MADDOX, and later independently discovered by BREFELD and by HECKE, that the loose smut of wheat and the smut of barley can infect the young ovary directly, and that these grains, apparently normal, produce smutted plants, he is led to the belief that the Lolium-fungus is a smut. The behavior and appearance of the smut-mycelium in these embryos is very similar to that of the Lolium-fungus, and strongly suggests a relationship between that fungus and the smuts.—H. HASSELBRING.

Contributions from Gray herbarium.[28]—In the most recent contribution of this series, ROBINSON has published some results of his studies in the Eupatorieae. There is a revision of Piquieria, 19 species being recognized, 4 described as new, and a new sub-genus (*Erythradenia*) established; also a revision of Ophryosporus, 17 species being recognized. Under the genus Helogyne its synonyms are discussed, and its 4 species described (one of them is new). A fourth part of the contribution gives diagnoses and synonymy of Eupatorieae and of certain other Compositae which have been classed with them, among which appear descriptions of 6 new species of Eupatorium.—J. M. C.

N. Am. Characeae.—ROBINSON[29] has published a synopsis of the North American species of Chareae, one of the two subfamilies of Characeae. Of the four genera making up this subfamily, only Chara has been collected in North America. Within the range assigned, 50 species are described as belonging to this genus, 16 of which are characterized as new.—J. M. C.

Assimilation of free nitrogen by fungi.—From a discussion of the results of recent work relating to the assimilation of free nitrogen by fungi, HEINZE[30] comes to the conclusion that elementary nitrogen is not assimilated by fungi other than bacteria. The article is useful in that it brings together all the literature relating to this subject.—H. HASSELBRING.

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27 FREEMAN, E. M., The affinities of the fungus of *Lolium temulentum* L. Annales Mycol. 4:32–34. 1906.

28 ROBINSON, B. L., Studies in the Eupatorieae. Contributions from the Gray Herbarium of Harvard University. N. S. No. 32. Proc. Amer. Acad. **42**:1–48. 1906.

29 ROBINSON, C. B., The Chareae of North America. Bull. N. Y. Bot. Gard. 4:244–308. 1906.

30 HEINZE, BERTHOLD, Sind Pilze imstande den elementaren Stickstoff der Luft zu verarbeiten und den Boden an Gesamtstickstoff anzureichern? Annales Mycol. 4:41–63. 1906.

NEWS.

The University of Vermont has conferred the degree of doctor of science on Mr. C. G. Pringle, keeper of the herbarium of the university.—Science.

Dr. Henry S. Conard, professor-elect of biology in Randolph-Macon College, has resigned to accept an appointment as professor of botany in Iowa College, at Grinnell, to succeed Professor Fink.

Professor R. B. Wylie, professor of biology in Morningside College, has been appointed assistant professor of botany in the University of Iowa, where he is to have especial charge of the work in plant morphology.

The appropriation for the Department of Agriculture for the fiscal year beginning July 1, 1906, aggregates $9,932,940. Among the items of interest to botanists are the following: Bureau of Plant Industry, $1,024,740; Forest Service, $1,017,500; Agricultural Experiment Stations, $974,860; Division of Publications, $248,520; Bureau of Soils, $221,460; Biological Survey, $52,000; Library, $25,880.

For two years the State Weather Service of Maryland has been carrying on a Botanical Survey of the State under the direction of Dr. Forrest Shreve, Johns Hopkins University. During the present summer two parties are in the field: one under Dr. Shreve, working in the Appalachian valley; and one under Mr. Frederick H. Blodgett, Maryland Agricultural College, working in the Blue Ridge region.

The Office of Experiment Stations of the United States Department of Agriculture has undertaken the preparation of a complete list of the books written by agricultural college and experiment station men in the United States. As a heritage from the Paris and St. Louis expositions the Office has a set of about two hundred books by experiment station men. A list of these and of a few others by the same authors has been prepared, and assistance is requested in completing the list. The Office desires to get copies of such books as are not now in its collection, so far as this is possible.

--The *Association internationale des botanistes* decided last year at Vienna to form an international organization to advance the interests of agriculture and horticulture by the selection, introduction, and distribution of plants useful for forests, fields, industrial supplies, or ornament. To this end a conference is to be held in Paris, August 25, at the building of the Horticultural Society, 84 rue de Grenelle, where it is expected to organize for this purpose a special section of the Association and to devise means for attaining promptly the ends in view. M. Philippe L. de Vilmorin is organizing this meeting, which gives promise of being successful, inasmuch as the cooperation of many *savants practiciens* and botanical gardens is already assured.

VOLUME XLII NUMBER 3

BOTANICAL GAZETTE

SEPTEMBER, 1906

DIFFERENTIATION OF SEX IN THALLUS GAMETOPHYTE AND SPOROPHYTE.[1]

ALBERT FRANCIS BLAKESLEE.

(WITH PLATE VI AND THREE FIGURES)

In a recent article (5) the writer has given a somewhat detailed account of zygospore germinations in certain species of the Mucorineae. The purpose of the present paper is to point out the bearing which the investigations already made in this group may have upon the questions of sexuality in other forms. Some of the problems for research which the facts observed in the mucors would suggest will be indicated, and it is hoped that in forms in which an alternation of generations occurs the distinction between differentiation of sex in the gametophyte and that in the sporophyte will be more clearly drawn than has been done previously. The various grades of differentiation in the gametes themselves or in the gametophyte and sporophyte will not be discussed. The subject for consideration rather will be the sexual condition in the plant as a whole.

According to the sexual character of their thalli, the species of the Mucorineae have been divided (2–6) into two main groups, homothallic and heterothallic—designations which correspond in the main to the terms hermaphroditic and dioecious respectively. In a homothallic species the thalli are all sexually equivalent, while in a heterothallic species the thalli are of two different kinds, which have been provisionally designated by the symbols (+) and (−). The sexual character of the (+) and (−) mycelia remains constant when

[1] This paper was written while working under a grant as research assistant of the Carnegie Institution, to whom the writer wishes to express his indebtedness for the opportunities for research afforded him.

they are grown separately in pure cultures. Thus the opposite strains of *Phycomyces* and *Mucor Mucedo* have been cultivated by means of sporangiospores to respectively 107 and 106 non-sexual generations without apparent change in their sexual behavior. This differentiation into (+) and (−) mycelia, which are capable of retaining their respective characters apparently for an indefinite number of vegetative generations, renders the heterothallic mucors as striking an example of dioecism as is to be found in the plant kingdom.

In those heterothallic species investigated in which a difference in vegetative growth is apparent, the (+) strain is the more luxuriant. In higher forms when a difference in size exists between the two sexes, the female is usually the larger. In such heterothallic forms the zygote develops entirely from the female thallus, and it would not seem unnatural that the thallus which supplies nourishment for the formation of the reproductive bodies should have a greater development than the thallus which produces only the comparatively small male gametes. The zygote of the heterothallic mucors, on the other hand, is formed by the union of morphologically equal gametes cut off from similar branches of the sexually opposite thalli. The zygospore is suspended midway between the (+) and (−) thalli which take equal share in supplying the nutriment for its development. The difference which sometimes exists in vegetative luxuriance between the two strains is independent therefore of the demands of the reproductive bodies, and is to be connected in some way with the primary sexual differentiation into the two opposite strains.

There are no heterothallic species as yet known in which a constant difference between the size of the two gametes has been observed. Two genera from the homothallic group are heterogamic, and in these forms the smaller gamete may be assumed to be male and the larger female. If it were found that a (+) test strain would show a reaction with the male, while the (−) strain showed a reaction with the female branch, one would have evidence for considering the (+) strain female and the (−) strain male. Unfortunately, attempts to hybridize test (+) and (−) heterothallic strains with these heterogamic forms have been as yet entirely unsuccessful. It is to be hoped that other heterogamic forms may be discovered which will lend themselves more readily to experiments in hybridization. That

as yet it has not been possible to substitute the terms male and female for (+) and (−), or *vice versa*, does not in the least detract from the conclusion, however, that the differentiation is a sexual one.

Forms characterized by gametes equal in size have been commonly classified as isogamous. The term, it need hardly be pointed out, can have only a morphological application among the mucors. Sexually the two gametes which unite have diametrically opposite characters. The mutual indifference of two mycelia of the same sex, and the active sexual reaction between mycelia of opposite sex which leads to the formation of zygospores when the mycelia are of the same species, and to the formation of imperfect hybrids when they are of two different species, indicate that the isogamy is by no means physiological. The classical researches of BERTHOLD (1) have shown that among the morphologically equivalent motile gametes of certain species of Ectocarpus there is a physiological differentiation into gametes which are attractive and those which are attracted, and a similar condition is met with among the Conjugatae. In the mucors the sexes seem to be equally attractive. If in other zygophytic forms the gametes are ever physiologically equivalent, their union can scarcely be considered a sexual process in the usual acceptation of the term.

The physiological differences which exist between the sexually opposite thalli of heterothallic mucors reaches morphological expression in those instances in which the (+) in comparison with the (−) strain is characterized by a greater vegetative luxuriance. Although the heterothallic forms are morphologically all isogamous, the sexual differentiation which they exhibit into two distinct races cannot be considered a lower grade of sexuality than the differentiation shown in the morphologically unequal gametes of the heterogamic species. Heterogamic forms are found only in the homothallic group. It would seem most reasonable to suppose that the isogamous homothallic forms were the more primitive, and had given rise on the one hand to heterogamic forms by a differentiation of the individual gametes, and on the other hand to heterothallic forms by a differentiation of the individual thalli. The partial transformation of the heterothallic species Phycomyces into a homothallic form which has been accomplished might, however, suggest the possibility of a deri-

vation of the homothallic forms from the heterothallic group. There are seven species known to be homothallic, among which three are heterogamic, while sixteen are known to be heterothallic. In all probability the large majority of the species which produce zygospores are heterothallic, yet the sexual character in but a small proportion of the mucors has been definitely determined, and it is unknown whether in this group species may not exist in which sexuality is entirely lacking. The writer has as yet no theories to offer as to the origin of sexuality in the group.

The fact that zygospores when germinating in a proper nutrient medium may give rise directly to a mycelium has led botanists to discard the idea of an alternation of generations comparable to that in higher plants, which was formerly seen in the succession from mycelia bearing sexually formed zygospores to germ tubes producing non-sexual sporangiospores which complete the cycle by the formation again of sexual mycelia. The cytological history of the formation and germination of the zygospores is at present too little known, and the writer would not care to be responsible for advocating as yet a too close homology between the conditions seen in the mucors and in the mosses for example, although the branching out of the germ tube under special conditions to form a mycelium might be considered of no great significance, since paralleled by the capacity of the moss sporophyte to give rise directly to a protonema. The gross analogy, however, between the germination of the zygote in mucors and that in the mosses is much more obvious than between the conditions in the mosses and those in the flowering plants or in animals (9), and is sufficiently close to justify one in concluding the mucors in a general comparison of the varying grades of sexual differentiation in the plant kingdom. In the accompanying diagrams and in the ensuing discussion, therefore, the same terminology will be applied to the mycelium and to the germ tube that has been found advisable for the gametophyte and sporophyte of forms in which it is at present orthodox to speak of an alternation of generations.

The terms dioecious, monoecious, and hermaphroditic have been used to designate varying grades of sexual differentiation, and have been applied to both gametophyte and sporophyte. Dioecism among

the bryophytes has been understood to signify the existence of two kinds of gametophytes, male and female, and the condition in the sporophyte has been disregarded; while among the flowering plants the usage is changed and dioecism has had reference solely to the sporophyte. An inspection of the accompanying diagrams will show that a plant which is monoecious as regards its sporophyte may be either monoecious or dioecious as regards its gametophyte; and on the other hand a plant dioecious in its gametophyte stage may be either monoecious or dioecious in its sporophyte stage. The first case is illustrated by the ferns, which are all dioecious monoecious in the sporophyte though having both conditions in the gametophyte; and the second case is illustrated by the flowering plants, whose sporophytes are either monoecious or dioecious, but whose gametophytes are always dioecious. In flowering plants and in ferns, one of the two generations is characterized by only a single sexual condition, and attention has accordingly been directed to the other generation in which both sexual conditions are present. That this inaccuracy in the terminology has been allowed to stand so long unchallenged is probably due to the tacit assumption that the condition in the ferns is typical for all the archegoniates. Up to the present time, however, the sexual condition in the sporophyte of forms below the ferns has never, so far as the writer is aware, been a subject of investigation or even of discussion.

The terms hermaphroditic, monoecious, and dioecious have established themselves in use, and have their place as technical designations in systematic botany of the flowering plants. As applied to the cryptogams, they have always been unsatisfactory, since the terms hermaphroditic and monoecious are used in descriptive botany to indicate whether the male and female sporophylls are produced in bisexual or unisexual flowers. In the cryptogams the terms lose their distinction with the passing out of use of the word flower. The greater or less local separation of the sexual organs or of the male and female sporophylls on a single individual is of little significance in comparison with the separation of the sexes on two entirely distinct individuals. Whether in Achlya, for example, the antheridia arise from the stalk which bears the oogonium as in *A. racemosa*, or are produced from separate special branches as in *A. prolifera*, is a

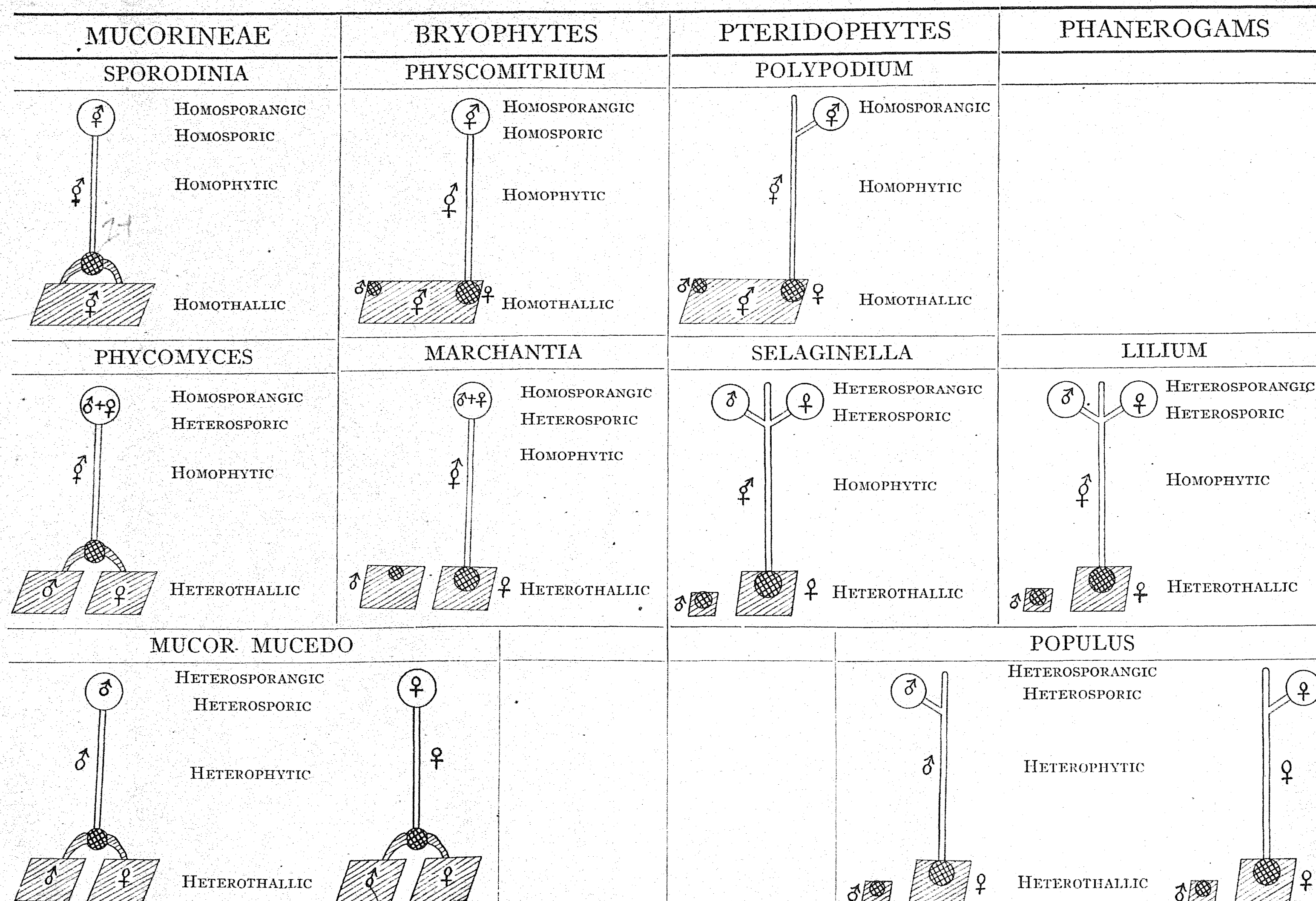
detail of somewhat minor importance. The sexual differentiation on a single mycelium in the latter species may be perhaps a forerunner of heterothallism, yet in each species the thallus as a whole is bisexual.

Rather than attempt to restrict the terms monoecious and dioecious to either the gametophytic or sporophytic stage, it has seemed best for the purposes of general discussion in the present article to avoid the ambiguity of the expressions now in use by applying a separate set of terms to designate the sexual condition in the gametophyte and sporophyte respectively. Whether or not the precision thereby gained will compensate for the disadvantages of adding new words to an already overburdened vocabulary of technical expressions must rest with botanists whose interest in the subjects of sexuality embraces all the groups of the plant kingdom.

Homothallic and heterothallic are terms already explained, which the writer has used to designate the species of the mucors characterized respectively by thalli sexually all alike, or by thalli sexually of two different kinds. Homothallic and heterothallic forms, therefore, have bisexual and unisexual thalli respectively, and the terms accordingly would correspond to the expressions monoecious and dioecious. Without changing the etymological significance, the meaning of the words homothallic and heterothallic may be appropriately extended to include a description of the degree of sexual differentiation in the prothallus or gametophyte of the archegoniates and spermatophytes, as well as in the thallus of the thallophytes.

Homophytic and *heterophytic* are offered as equivalents in the sporophyte of the terms monoecious and dioecious. Although the "plant" in the common acceptation of the word is the sporophyte in the higher forms, the condition is reversed in the bryophytes. The words homophytic and heterophytic, therefore, as designations for the sporophyte are etymologically not above reproach, but will suffice in lieu of a more cumbersome combination. The terminology suggested has reference to the sexual differentiation as such. The accompanying morphological differences are to be considered as secondary sexual characters and are not included in the classification.

It will now be possible to examine the sexual condition in the


MUCORINEAE
SPORODINIA
HOMOSPORANGIC
HOMOSPORIC
HOMOPHYTIC
HOMOTHALLIC
PHYCOMYCES
HOMOSPORANGIC
HETEROSPORIC
HOMOPHYTIC
HETEROTHALLIC
MUCOR MUCEDO
HETEROSPORANGIC
HETEROSPORIC
HETEROPHYTIC
HETEROTHALLIC
BRYOPHYTES
PHYSCOMITRIUM
HOMOSPORANGIC
HOMOSPORIC
HOMOPHYTIC
HOMOTHALLIC
MARCHANTIA
HOMOSPORANGIC
HETEROSPORIC
HOMOPHYTIC
HETEROTHALLIC
PTERIDOPHYTES
POLYPODIUM
HOMOSPORANGIC
HOMOPHYTIC
HOMOTHALLIC
SELAGINELLA
HETEROSPORANGIC
HETEROSPORIC
HOMOPHYTIC
HETEROTHALLIC
PHANEROGAMS
LILIUM
HETEROSPORANGIC
HETEROSPORIC
HOMOPHYTIC
HETEROTHALLIC
POPULUS
HETEROSPORANGIC
HETEROSPORIC
HETEROPHYTIC
HETEROTHALLIC

groups represented in the accompanying diagrams. In all the figures the gametophyte has been shaded with parallel lines, the antheridia and zygotes with cross-hatching; while the sporophyte and the sporangia have been left unshaded. The drawings are entirely diagrammatic, and no attempt has been made, therefore, to preserve the relative proportions of the parts figured. As has been already explained, the Mucorineae have been included in this scheme for the purpose of comparison, and the germ tube has been thus homologized with the sporophyte. The mucors then as represented in the first column in the diagram are the only group outlined in which all the three main types of sexual differentiation are as yet known.

In *Sporodinia grandis*, which may be taken as representative of the homothallic group, the mycelium (gametophyte), the germ tube (sporophyte), and the germ sporangia are all alike bisexual. The two opposed gametes, and perhaps the branches from which they are cut off, may not unreasonably be considered unisexual and of opposite sex. It has not been found possible as yet, however, to confirm this assumption experimentally. In the terminology adopted the species is to be considered homothallic, homophytic, homosporic, and homosporangic. The same condition is found in the "monoecious" mosses represented by *Physcomitrium pyriforme*, and in the homosporous ferns represented by Polypodium. The sporangium of the latter is represented as a side branch, since in the ferns, as also in the flowering plants, the sporangia are not simple terminations of unbranched sporophytes of limited growth, as in the bryophytes, but are borne on the sporophylls of a sporophyte more or less highly developed.

If the sexual character of the thallus be preserved, the spores and the sporophyte producing them must be also bisexual. There can be only one type therefore of homothallic forms. Of heterothallic forms, on the contrary, two types are possible—namely, those with bisexual sporophytes, *i. e.*, homophytic, and those with unisexual sporophytes, *i. e.*, heterophytic. These two types are represented by *Phycomyces nitens* and *Mucor Mucedo* respectively.

In the heterothallic species Phycomyces it will be convenient for the purposes of the present paper to neglect those instances in which the germination follows the *Mucor Mucedo* type, as well as the

occasional formation of homothallic spores in the germ sporangia, and to consider as typical the condition shown in the diagram. For a more detailed account of the zygospore germination in Phycomyces, as well as for the characters of the homothallic form into which this heterothallic species has been transformed, one must refer to the paper on zygospore germinations already cited. In the type, perhaps somewhat arbitrarily selected for discussion, the germinations are mixed—both male and female spores being produced in a single germ sporangium. The mycelia in this species are unisexual, the zygospores and germ tubes are bisexual, and the spores in the germ sporangia are unisexual. If the germ tube be forced to form a mycelium without the intervention of sporangiospores, a bisexual, *i. e.*, homothallic, mycelium results, which may produce typical homothallic zygospores. Phycomyces as discussed, therefore, is heterothallic, homophytic, heterosporic, and homosporangic.

In the bryophytes, *Marchantia polymorpha* is the only form which has been investigated in regard to the sexual condition of its sporophyte (cf. p. 170). Its gametophyte shows a differentiation into male and female thalli, and the germination of the zygote produces a sporophyte which bears a sporangium containing both male and female spores. Marchantia, therefore, like Phycomyces is heterothallic, homophytic, heterosporic, and homosporangic.

Selaginella, as a representative of the heterosporous ferns, follows in the main the Phycomyces type. It differs from Phycomyces and Marchantia, however, in that it is heterosporangic—the male and female spores being separated in microsporangia and macrosporangia. The spores themselves, moreover, are morphologically of two kinds, the female or macrospores being conspicuously larger than the male or microspores. This morphological differentiation of the spores and sporangia is known only in the heterosporous ferns and in the flowering plants, and is accompanied by a reduction in the size of the gametophyte. Among the homosporous ferns, prothalli are often found with only archegonia or antheridia, and investigators have been able to suppress the formation of one or the other in certain species where archegonia and antheridia occur normally side by side on the same prothallus. The writer is aware, however, of no form

among the homosporous ferns which investigators have shown to be strictly heterothallic.

In the monoecious and hermaphroditic phanerogams, illustrated by Lilium, the condition is essentially the same as in Selaginella, with a differentiation into macrospores and microspores, and like the latter species the type may be described as heterothallic, homophytic, heterosporic, and heterosporangic.

The homophytic division of the heterothallic group illustrated by Phycomyces is the only one of the three types that has representatives in all the orders outlined.

Mucor Mucedo represents the heterophytic division of the heterothallic group. In contrast to Phycomyces, the zygospores of this heterothallic species furnish pure germinations, but the spores are unisexual; and while the germ tube and the sporangiospores produced from one zygospore are male, those produced from another may be female. There are, therefore, two different kinds of germ tubes, of sporangiospores, and of sporangia, as well as two different kinds of mycelia. These elements in this species show no more recognizable morphological differences than its mycelia, although the sexual differentiation seems to be as marked as in forms in which such a morphological differentiation exists throughout the whole plant. *Mucor Mucedo* is heterothallic, heterophytic, heterosporic, and heterosporangic.

Since Marchantia is the only heterothallic form among the bryophytes the sexual character of whose sporophyte has been investigated, it is as yet unknown whether any forms of the mosses and liverworts exist corresponding to the *Mucor Mucedo* type.

No heterophytic forms are known at present among the heterothallic pteridophytes, and it will be impossible to say whether they ever existed in geologic times. The non-appearance of one reproductive form on a given sporophyte cannot be taken at once as proof that the species is heterophytic. It not infrequently happens, for example, that one finds only microsporangia on a single individual of Selaginella. Such instances may be compared to the suppression of the organs of one sex on the prothalli of homothallic ferns, and may equally be explained by assuming that the conditions necessary for the formation of the two reproductive bodies do not always coincide.

The "dioecious" phanerogams, represented by the heterophytic form Populus, follow closely the *Mucor Mucedo* type. They differ from *Mucor Mucedo* in that the sexual differentiation has reached a morphological expression, and the sex of the thalli, spores, and sporangia is at once distinguishable. In general the male and female sporophytes are alike in appearance, but in the sporophytes of some forms the sexes are easily distinguished. Perhaps the best known example among the common trees is the Lombardy poplar (*Populus pyramidalis*), which in male specimens has been widely cultivated for the sake of its pyramidal form. The female trees have a spreading habit of growth and are seldom to be found in cultivation.

In the diagram three squares are left blank. In the flowering plants heterothallism has become fixed and no forms of the Sporodinia type exist. There is no reason apparent why heterophytic forms should not occur among the heterothallic pteridophytes. The fact remains that all the existing heterothallic species are homophytic. The blank squares in the phanerogams and pteridophytes must therefore remain unfilled. Little is known about the sexual differentiation in the bryophytes, and it must rest with future research, therefore, to determine whether or not they possess heterophytic representatives in the heterothallic group.

In light of the conditions found in the Mucorineae, the heterothallic bryophytes, as already pointed out by the writer (*l. c.*, p. 25), offer a most interesting field for investigation. Accordingly attention was directed to the heterothallic form *Marchantia polymorpha*, which, according to the unpublished observations of NOLL as reported by SCHULTZE (17), retains the unisexual character of the individual thalli when propagated vegetatively by gemmae.

During the last November, Marchantia was found in fruit and sowings were made from individual sporangia, and the young plants resulting from their germination were isolated and transplanted in such a manner that at fructification it would be possible to determine the sex of the individual spores from which they were derived. While the present paper was largely in manuscript, the writer learned of unpublished observations made by NOLL on this same species. Professor NOLL, to whom the writer is greatly indebted for the information communicated, has cultivated Marchantia by means of gemmae

for over thirty generations of both male and female strains, without having been able to change the sexual character of the thalli by subjecting them to varying conditions of growth. The form is therefore strictly heterothallic. Moreover, in a single instance a sporangium was made to discharge its spores on a pot of earth, and male and female fructifications were obtained from the mixed growth of thalli resulting from their germination. Marchantia is therefore homophytic, and it now becomes possible to fill out in the diagram one of the two squares which in the bryophytes had been left blank pending the fructification of the young thalli which the writer had obtained from isolated spore germinations.[2]

In Phycomyces, with which Marchantia is to be compared, there seems to be no definite relation between the number of male to female spores formed in a germ sporangium, and it may even happen that all the spores are of the same sex. Moreover, it is not infrequently the case that in a small per cent. of the spores in a germ sporangium the segregation into male and female has not been completed. These bisexual spores produce homothallic mycelia. Cultures from individual spores will be necessary to determine for Marchantia the proportion of male to female spores in a single sporangium, and to ascertain if, in addition to the normally unisexual spores, bisexual spores are ever formed, as is the case in Phycomyces.

The bisexual germ tube of Phycomyces may be cut and forced to branch out to a homothallic mycelium. The observations of NOLL and of the writer have shown Marchantia to be homophytic. Its sporophyte as a whole, therefore, must be bisexual, and every cell formed before the determination of the sex of the spores, if brought to develop into a new plant, should theoretically produce homothallic individuals. PRINGSHEIM (16), STAHL (18), and CORRENS (10), among others, have obtained protonemata from the sporophytes of mosses. No one, however, seems to have succeeded in obtaining regeneration from the sporophyte of liverworts. The writer has experimented with mature sporophytes of Fegatella and with sporophytes of Marchantia of various ages, but has been unable to secure any growth from them.

[2] While the present paper is in press, 12 thalli have so far produced fructifications out of a total of 113 which were obtained from as many spores from a single sporangium. Of these nine are male and three are female.

In the investigation of the typical germinations of Phycomyces, it has been shown that the determination of sex does not occur in the zygote, but that an interval in the form of a germ tube is interpolated between the zygote and the germ sporangium where the segregation of sex finally occurs. The essential difference between Phycomyces and Marchantia lies in the fact that in the former the interval is a single-celled multinucleate structure arising from a multinucleate zygospore, while in the latter the interval is made up of many uninucleate cells arising from a uninucleate oospore. In Marchantia the segregation of sex undoubtedly takes place at some point in the maturation of the sporangium. If the archesporium and the spore mother cells prove capable of germinating, and it be possible in the thalli which result to recognize the presence of both sexes when the plants are homothallic, one may be in a position to determine the exact point where the segregation of sex occurs and to discover what relation if any the segregation may have to the reduction division or to other nuclear phenomena.

The predominance of organs of a single sex on the prothallus of the ferns due to conditions of growth and the similar phenomenon in the sporophyte of Selaginella may lead to the non-appearance of the other sex. Such a suppression of sex, however, is not to be confused with sex determination. By cultivating fern prothalli under unfavorable conditions of nutriment, PRANTL (15) was able to confine the production of sexual organs to antheridia. The archegonia demand a prothallus furnished with meristematic tissue, and consequently on a poorly nourished prothallus which has developed no meristem only antheridia can be formed. If prothalli which are producing exclusively antheridia be removed from a culture medium containing no available nitrogen, to a medium in which available nitrogen is present in sufficient amount, meristematic tissue is developed upon which archegonia are formed. KLEBS (12), moreover, has shown that by reducing the amount of light to which they are exposed prothalli may be brought to a prolonged vegetative growth, and thus the formation of both antheridia and archegonia may be suppressed. Professor KLEBS has informed the writer that when the amount of light is increased to a certain extent, antheridia alone are produced from these sterile prothalli,

but that to obtain archegonia, they must be exposed to a still greater illumination. BUCHTIEN (7) has shown that in Equisetum external conditions have a similar influence upon the apparent sex of the prothalli.

As yet attempts to influence arbitrarily the sex in unisexual plants have entirely failed. Even though it remain impossible to change the sex in the thalli of Marchantia, it may be found that, by experimenting on the sporophyte where we must assume the sex is unsegregated, one may be in a position to bring about the exclusive production of either male or female spores in a given sporangium. Such a result if accomplished would be analogous to the suppression of one set of sexual organs on the prothalli of ferns.

The behavior of the gametophyte of homothallic ferns and that of the sporophyte of such heterophytic flowering plants as *Melandrium album* (19) shows that, abnormally in certain forms and normally in others, only one sex may make its appearance. The conclusion suggested by an assemblage of facts, especially from the animal kingdom, is generally accepted that in so-called unisexual forms one sex is dominant and finds expression in the formation of gametes or spores of the given sex, while the opposite sex exists in a latent condition. However probable such a conclusion may appear for the majority of forms investigated, it must be admitted as at least a possibility that in certain plants or in certain stages a single sex may exist in a pure condition. The fact that besides the occasional production of unisexual germ tubes the zygote of Phycomyces gives rise typically to germ tubes in which the differentiation of sex has not taken place is proof neither for nor against the purity of the male and female thalli, and suggests that the not infrequent occurrence among heterophytic flowering plants of individuals with male and female flowers is as much an indication that both pure and mixed conditions may exist in the sporophyte of these plants as a proof that in heterophytic plants the opposite sex always exists in a latent condition. The germinations of the zygotes of Phycomyces and Marchantia suggest the possibility that the sex may be pure in the gametophyte while mixed in the sporophyte. The observations on unisexual plants, however, have been as yet confined almost entirely to the sporophytic stage, and little is known as to how strict

the differentiation of sex actually is in plants in the gametophytic stage.

Unless the gametes contain both sexes, parthenogenesis in homothallic forms should give rise to unisexual individuals—the male gamete to male and the female gamete to female individuals. So far as the writer is aware, no investigations have been undertaken with a view to confirm this assumption experimentally. Attempts made by the writer to determine the sexual character in the gametes of homothallic mucors by means of their germination before or after their transformation to azygospores have not as yet been successful. In the higher plants, parthenogenesis in the sense of the development of an individual from a sperm or egg cell with the reduced number of chromosomes is, so far as the writer is aware, not definitely known to occur. The sex in the apogamous seeds of Taraxacum for example, however, must contain male characters if the plants produced from them develop stamens, as seems regularly to be the case.

What the essential difference between sex actually is, is as yet beyond conjecture, and the significance of sex in organic development is at present a subject of conflicting discussion. It is to be hoped that a further study, especially of lower forms, where the gametes are more closely connected with the vegetative portions and the zygotes formed by their union more accessible to manipulation, may lead to a better understanding of some of the fundamental problems of sexuality. The present brief article is no place for any detailed discussion of sexuality in the various groups of plants. For a short general presentation of the subject, the reader may refer to the recent work of KÜSTER (13) and to the literature therein cited. It seems not out of place, however, to say a few words in regard to the thallic differentiation in the lower cryptogams, where the subject has received little attention.

Unisexual and bisexual forms occur throughout the plant kingdom, and are often to be found in the same genera. This sexual differentiation seems to have no relation to the stage of phylogenetic development. Thus while in higher animals the unisexual condition predominates, in higher plants the monoecious, *i. e.* homophytic, condition is the more common. Again, the majority of the ferns

are homothallic, while the majority of the mucors investigated are heterothallic. Both conditions, therefore, may be expected *a priori* in any group under investigation, whatever may be its phylogenetic rank.

In groups in which sexuality is present, in both fungi and algae, there are many forms for which the sexual spores have been but rarely found or are entirely unknown. The absence of sexual reproduction may be due (1) to constitutional sterility, (2) to conditions of growth unfavorable to the production of sexual organs, or (3) to the fact that the form is heterothallic and thalli of both sexes have not been found together. In the last case the apparent sterility would not be due to a lack but rather to an excess of sexuality which separates the male and female individuals. Even in heterothallic species, neutral races have been found to exist, and the conditions within which sexual reproduction is possible are frequently very limited.

A morphological investigation may suffice to show that the male and female organs are borne on the same thallus, and the form in question can then be at once classified as homothallic. A heterothallic condition, on the other hand, can never be recognized by a morphological investigation alone. The appearance of but one set of sexual organs on an individual form studied under the microscope may be due either to dichogamy or to suppression of the other sex brought about by conditions of growth, as well as to a unisexual character of the thalli. Carefully conducted cultures are therefore essential to a determination of the sexual character of forms investigated. A few examples may be briefly given to illustrate the necessity of employing the cultural method in a study of even well-known forms. Many other examples equally as appropriate will suggest themselves to the reader.

In the mosses the leafy shoots arise from an inconspicuous protonema, and if certain shoots bear only antheridia and others only archegonia, a cursory investigation would lead one to consider the forms heterothallic, especially if the antheridial and archegonial "plants" differ in appearance. *Funaria hygrometrica*, for example, is classified as monoecious bv LIMPRICHT (**14**) and CORRENS (**10**), yet CAMPBELL (**8**, p. 187) says "Funaria is strictly dioecious." The

term here is perhaps used in reference to the constant separation of the sexual organs on different shoots without regard to their ultimate connection on the protonema; yet the latter is as an essential part of the plant as the leafy axis, and if the species is in fact homothallic it is not to be called dioecious. Such forms as Funaria offer an interesting field for regeneration experiments to determine if protonemata developed from antheridial and archegonial shoots differ at all in sexual character.

Among the algae, Spirogyra, to mention a simple example, is a familiar genus in which homothallic species are known to occur, and in which heterothallism is strongly to be suspected for certain species from a mere morphological investigation. In *fig. 1*, which is taken from STRASBURGER'S textbook, is represented *Spirogyra longata*. It seems in this type to be a matter of indifference whether the two conjugating cells come from the same or from different threads. Obviously here the filaments are bisexual and the species is therefore homothallic. In Debarya, represented in *fig. 2*, the zygospores are formed, as in the heterothallic mucors, midway between the two thalli, between which no differences are apparent. In the most common form of conjugation, however, which is represented in *fig. 3*, one filament seems to be receptive, since it contains all the zygotes formed between two conjugating filaments and has therefore been considered female. Though rather improbable, it is yet imaginable that a filament which acts as female toward one thread might function as male toward another. Theoretically it would not be a difficult task to determine by cultivation the sexual character of any form found producing zygospores.

FIG. 1 Spirogyra

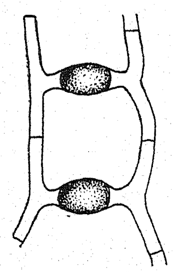


FIG. 2 Debarya

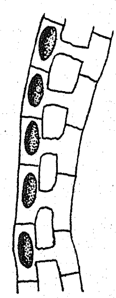


FIG. 3 Spirogyra

The Saprolegniaceae form sexually one of the most interesting groups among the fungi. In *Achlya racemosa* the antheridial branches are borne from the stalk of the oogonium, in *A. polyandra*

they arise fom differentiated branches which are only distantly connected with the hyphae which bear the oogonia, and in *Saprolegnia dioica* and *S. anisospora* we have forms which have been described as dioecious. Cultural investigation alone can determine whether these latter forms are in fact heterothallic. It is perhaps significant that in this group forms have been found which have remained sterile under cultivation (*cf.* HORN, **11**. p. 232). It is not improbable that they may represent unmated strains of heterothallic species.

Of especial interest will be an investigation for the possible occurrence of two sexual races in groups such as the desmids, the flagellates, and the infusoria, where the whole vegetative organism functions directly as the gamete.

Among the cryptogams, with the exception of the mucors and Marchantia, the sexual relations of the offspring from a single zygote in heterothallic forms, the zygotes of which give rise to more than a single individual, have never been investigated. The condition in the bryophytes has been already discussed under Marchantia. In the thallophytes writers see an alternation of generations variously expressed or suggested in the interpolation of carpospores between the fertilized zygote and the young plant. Whether in the heterothallic oedogoniums, to mention but a single example, the four carpozoospores formed at the germination of the oospore are always all of the same sex, like the germ spores in *Mucor Mucedo*, or may be some male and some female, like the germ spores in Phycomyces, can be decided only by an investigation of the individual thalli which they produce. If species in the Saprolegniaceae and Peronosporeaceae are found to be heterothallic, these forms will likewise furnish a fruitful field for investigation.

The discussion in the foregoing pages is based for the most part upon investigations done or already in progress in the Botanical Institute in Halle. The writer wishes to express his grateful appreciation to Professor KLEBS for the facilities of the laboratory and for his unfailing sympathy in the researches undertaken.

PARIS, April, 1906.

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A STUDY OF THE VEGETATION OF THE MESA REGION EAST OF PIKE'S PEAK: THE BOUTELOUA FORMATION.

II. DEVELOPMENT OF THE FORMATION.

H. L. SHANTZ.

(WITH SIX FIGURES)

IN an earlier paper[1] the writer has discussed the structure of the Bouteloua formation, and to this publication the reader is referred for general introductory matter. Space will not permit the inclusion here of lists of species in the formations of minor importance, which have to do with the development of this formation. The foothill thicket formation, the plains ruderal formation, and the plains bank formation are each made up of many species. Only the facies and a few of the more important principal species can be mentioned.

Invasion by formations.

FOOTHILL THICKET FORMATION.

This formation extends along the eastern base of the mountains and down along the ridges and gullies far out on the plains. It forms a distinct zone at the base of the mountains (*fig. 8*) and here occurs in its best developed form. In most places under natural conditions there seems to be an ecotone, a place of equal aggressiveness, between this formation and the Bouteloua formation.

FACIES: Cercocarpus parvifolius H. & A., Rhus trilobata Nutt., Quercus novo-mexicana (DC.) Rydb., Q. utahensis (DC.) Rydb., Q. Gambellii Nutt.

PRINCIPAL SPECIES: Rubus deliciosus James, Holodiscus dumosus (Nutt.) Heller, Ribes cereum Dougl., R. leptanthum Gray, R. pumilum Nutt.

In addition to those named there are about one hundred principal and secondary species.

This formation and the Bouteloua formation seldom mix, because where the shrubs grow the facies of the grass formation cannot exist. Nearer the mountains and along the hillsides they alternate sharply.

While the climatic and soil conditions are identical, the differ-

[1] BOT. GAZETTE 42:16–47. 1906.

ence in cover causes great difference in physical factors. Simultaneous physical factor readings show very clearly these differences. The following is a typical set:

Aug. 3, 1904, 10:45 a. m.

	Light	Temperature					Rel. humidity		Water content
		Soil	Soil surface	Plant surface	10^{cm}	1^{m}	10^{cm}	1^{m}	
Open............	6s	24°	50°	44°	29°6	28°4	40%	32%	3.6%
Thicket (Quercus)	180s	18°	30°	28°2	27°2	26°8	42%	39%	8.3%

FIG. 8.—Zonation at Palmer Park; frontal zone of *Bouteloua oligostachya* and *Artemisia frigida;* zone near base of the bluff *Andropogon furcatus;* at the base of the bluff the foothill thicket (Quercus); the bluff showing pine formation (*P. scopulorum*).

These conditions existed on the same exposures and 6^{m} apart. The open quadrat was dominated by *Bouteloua oligostachya* and *Artemisia frigida;* while the shaded quadrat contained *Quercus utahensis*,

Coleosanthus umbellatus, *Oryzopsis micrantha*, *Elymus condensatus*, *Filix fragilis*, and *Bryum argenteum*. The thicket was rather open, as may be seen at once by the light readings, the ratio of which is $\frac{1}{30}$. This ratio often becomes $\frac{1}{60}$, but is usually less for the greater part of the formation.

Along the ridges north and east of Colorado Springs there is certain evidence that the thicket formation is slowly pushing its way out into the grass formation. Of the shrubs *Cercocarpus parvifolius* seems best adapted for this invasion, and it is several miles in advance of any of the other dominant species (*fig. 9*). Nearer the mountains

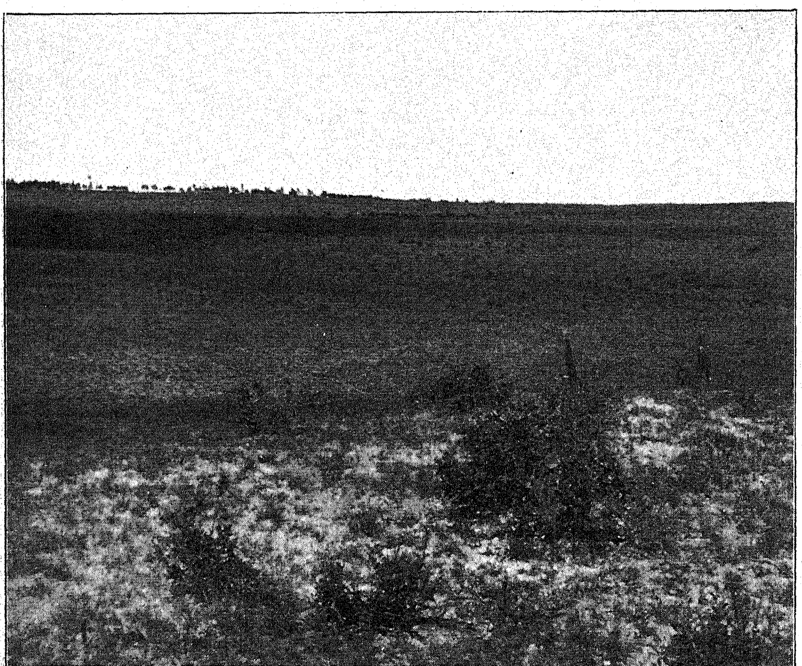

FIG. 9.—*Cercocarpus parvifolius* invading the Bouteloua formation; pine formation on the horizon.

evidence is also found of the invasion of the grass formation by the thicket formation. This invasion, however, is not rapid. As soon as the young shrub is established or has grown to sufficient size to produce shade, the grass formation gives way rapidly to species

of the thicket formation. Among the first species to appear in the shade of these advancing shrubs are *Calochortus Gunnisonii, Mertensia linearis*, and *Stipa neo-mexicana*. Later, when the habitat has been rendered less xerophytic and when the other facies have entered, *Coleosanthus umbellatus, Oryzopsis micrantha, Elymus condensatus, Selaginella rupestris Fendleri, Filix fragilis*, and a number of other species appear.

Under perfectly natural conditions and without the intervention of herbivora, the thicket would undoubtedly replace the greater part of the grass near the mountains, but, as is seen later, the thicket is slowly giving way and the grass formation is advancing.

PLAINS RUDERAL FORMATION.

FACIES: Stipa Vaseyi Scribn., Puccinia Stipae Arth., Boebera papposa (Vent.) Rydb., Helianthus petiolaris Nutt., Puccinia Helianthi Schw., Thelesperma intermedium Rydb., Verbena bracteosa Michx., Amaranthus blitoides S. Wats.

PRINCIPAL SPECIES: Salvia lanceolata Willd., Lappula occidentalis (Wats.) Greene, Polygonum aviculare L., Erysiphe Polygoni DC., Munroa squarrosa (Nutt.) Torr., Salsola Tragus L., Euphorbia glyptosperma Engelm., Malvastrum coccineum (Pursh) Gray, Puccinia Malvastri Pk., Vicia americana, Aecidium porosum Pk., Solanum rostratum Dunal, Helianthus annuus L., Cleome serrulata Pursh, Schedonnardus paniculatus (Nutt.) Trelease, Atriplex argentea Nutt., Senecio spartioides Torr. & Gray, Verbesina encelioides (Cav.) Gray, Helianthus petiolaris Nutt., Puccinia Helianthi Schw., Picradeniopsis oppositifolia (Nutt.) Rydb.

The secondary species of this formation are very numerous.

The physical factors of this formation are practically the same as those given for the Bouteloua formation. The conditions of water content are such that the most common ruderals, eastern and European species, cannot thrive to the best advantage. Many native plants behave as ruderals and this name is applied to the formation. This formation represents many different stages in a succession which will result ultimately in the grass formation, and is always invaded by the plants of the grass formation. Only a few of the ruderal species succeed in the grass formation. The most important of these is *Boebera papposa*, occurring everywhere throughout the formation and sometimes very abundant. It is much better developed in a ruderal position and is regarded as a part of the ruderal formation. *Stipa Vaseyi*, another native plant, succeeds best in ruderal positions, but is often found as part of the formation.

The species of the ruderal formation are almost entirely native plants which readily invade any area from which the vegetative covering has been removed. Of the true ruderals, *Salsola Tragus* pushes its way into the formation proper. Here it occurs as dwarfed plants which seldom branch, and which die during the aestival period. *Leptilon canadense*, which occurs only here and there in the ruderal formation, also occurs throughout the grass formation. The plants are usually reduced to 10^{cm} in height.

PLAINS BANK FORMATION.

Whenever a ditch is made through the grass or other formations, or where the grass formation is irrigated, the bank formation comes in. It matters not what kind of soil, the presence of an abundance of water enables this formation to succeed. This, however, is not true invasion, and comes about only as a result of changed conditions which make the existence of the grass formation impossible. Good examples of the coming in of the bank formation may be found in irrigated meadows and in small areas where irrigation ditches or reservoirs have leaked.

A study of this formation is of the greatest interest, for it is along this formation that the eastern species find their way into the region. The reason is obvious, for here they find suitable conditions of water supply. As a result, it is here that the vegetation is made up of the most widely distributed species.

The mountain species find in this formation the cool temperature that enables them to exist away from their natural habitats. These species pass down along the brook banks, while the eastern species pass up along these same banks. The result is a varied flora.

The radical difference in water content between this formation and the Bouteloua formation does not permit of direct invasion. The following species, however, may occur in either formation: *Erigeron flagellaris*, *Agropyron occidentale*, *Helianthus annuus*, *H. petiolaris*.

The facies of the bank formation varies greatly with the age of the formation. In the ultimate stage they are as follows:

Populus deltoides Marsh., P. angustifolia James, P. acuminata Rydb., Salix spp., Prunus melanocarpa (A. Nels.) Rydb., P. americana Marsh., Rosa Sayi

Schwein., Ribes aureum Pursh, Clematis ligusticifolia Nutt., Symphoricarpos occidentalis Hook., Rhus trilobata Nutt.

In an earlier stage this formation is found best developed in the irrigated meadows where *Poa pratensis* L., *Eragrostis alba* L., *Juncus balticus* Willd., *Heleocharis palustris* (L.) R. & S., and *Medicago sativa* L. may rank as facies.

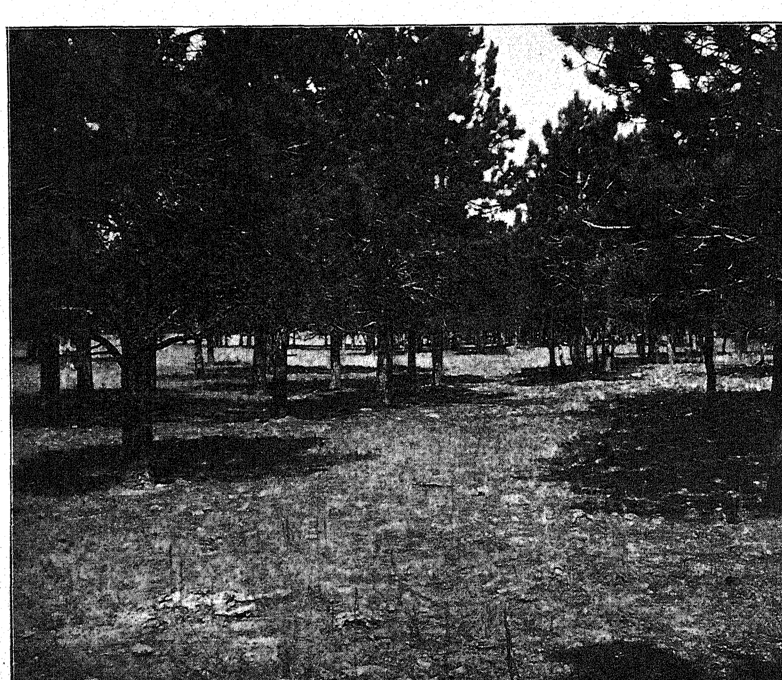

Fig. 10.—Floor of the pine formation (*P. scopulorum*) covered with the Bouteloua formation (*B. oligostachya, Koeleria cristata,* and *Artemisia canadensis*).

Xanthium commune and *Melilotus alba* are among the very first plants to enter on a newly formed ditch bank. In this formation are found many of the common species which occur in mesophytic situations in the eastern part of the United States.

PINE FORMATIONS.

As CLEMENTS[2] has pointed out, there are two pine formations near the base of the mountain range, the "foothill woodland" and

[2] Univ. Neb. Studies 4: no. 4. 1904.

the "pine." The first has as facies *Pinus edulis* Engelm. and *Juniperus monosperma* (Engelm.) Sarg.; and as principal species, *Stipa Scribneri* Vasey. The second has as facies *Pinus scopulorum* (Engelm.) Lem. and *P. flexilis* James.; and as principal species, *Arctostaphylos Uva-ursi* (L.) Spreng.

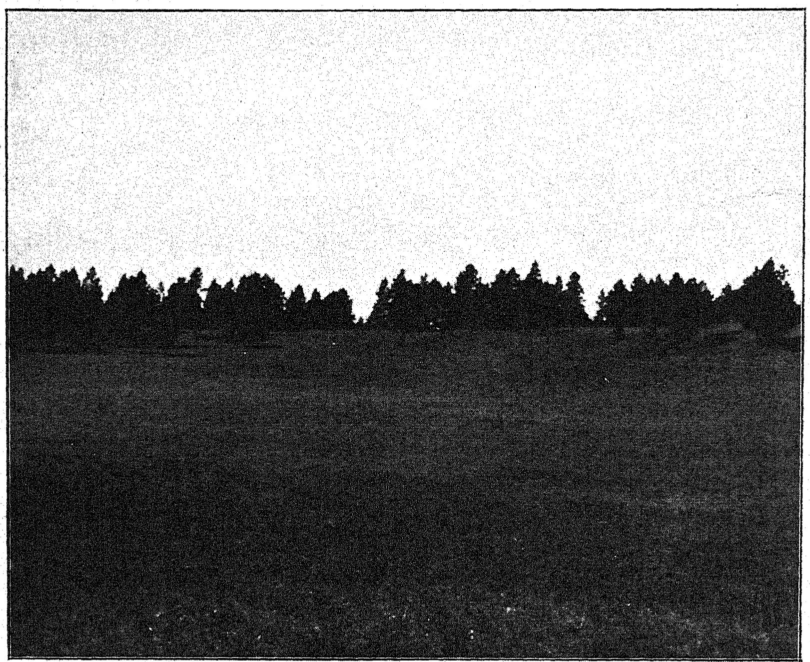

FIG. 11.—*Pinus scopulorum* invading the Bouteloua formation.

In the zone at the base of the mountains lies the foothill woodland formation, while just above is the pine formation. Each of these formations is invading the Bouteloua formation, and the one which lies higher on the mountains, the pine formation, is the more successful.

A consocies of this formation dominated by *Pinus scopulorum* has pushed its way eastward far into Nebraska[3] and carries with it many of the principal and secondary species. *P. flexilis* drops out before the foothills are reached. Near Eastonville, Colo., this formation

[3] POUND and CLEMENTS, Phytogeography of Nebraska, 2d ed., Lincoln, Neb., 1900, p. 336.

may be seen meeting the Boutcloua formation. All along this ridge the thicket formation has dropped out and the pines advance alone. The forest is not dense, and while many of the principal and secondary species are found on its floor, plants are also found which belong to the grass formation and which are able to survive in this location. In fact, the grass formation is found here in places dominating the floor of the pine formation—a true mixing of the formations (*fig. 10*). This mixing may be due to a certain extent to the entrance of the dominant species of the grass formation, but it is more likely to be the result of the gradual advance of the pines into the grass formation. This is shown very clearly in places where the young pines are several meters in advance of the older trees (*fig. 11*). This invasion may be observed along the ridge leading eastward from Palmer Lake and on which is found the so-called "black forest." Here the pines and the grasses mix and there are no shrubs present (*fig. 10*). The principal species, *Arctostaphylos Uva-ursi*, is also pushing out into the grass formation. A short distance west of Pring, Colo., this pine formation may be seen rapidly advancing along an old roadbed.

An entirely different condition may be observed eleven miles east of Colorado Springs. Here the pine formation is also advancing, but it is accompanied or rather preceded by the thicket formation. The advance of these two formations is favored by the cutting back of the gullies, forming steep hillsides, which offer the most favorable conditions for the growth of these two invading formations.

In many places the thicket, pine, and grass formations are found to meet and mix equally, the grasses forming the floor between the shrubs, and the pine scattered throughout. These three important formations are not only found meeting here on equal terms, but a remnant of an older formation, or at least one which gives evidence of greater age, is also found. This is the foothill woodland. *Juniperus monosperma* is scattered here and there and isolated trees of this species are often found which seem to be very old. Still stronger evidence is found in the fact that here, many miles removed from its fellows, is a very large and apparently very old *Pinus edulis*. Erosion has removed the soil from the base of the tree, exposing the roots, and it is certainly much older than any of the other trees

in this region. It is the only tree which supports a rich lichen flora.

Four important formations are found meeting and mixing here: the oldest, the foothill woodland, which has almost disappeared; the pine formation, which is slowly advancing; the thicket formation, which is also gradually advancing; and the grass formation, which gives way as the others advance. The thicket formation at this point entirely lacks the oaks, which fact is probably due to grazing.

In another part of the grass formation there is evidence of a slight advance of the foothill woodland. Young trees of *Juniperus monosperma* have established themselves in a few places on the mesa. In other places *Stipa Scribneri* is entering the plains region along with the thicket formation. The preponderance of evidence, however, seems to be in favor of a recession of this formation, and there is good reason to believe that it was at one time more extensive than at present.

Many species which seem to be most at home in the mountain formations also push down into the Bouteloua formation. Among these may be noted *Achillea lanosa*, extending down the draws, *Geranium caespitosum*, *Gilia pinnatifida*, *G. aggregata*, *Campanula petiolata*, and many other species.

Succession.

PRIMARY SUCCESSION.

On rock.

What the primary succession has been in this region cannot be determined. The succession on rock undoubtedly began with the lichen. On the most exposed rocks of the lime ridge *Staurothele umbrina* and *Lecanora previgna* are practically the only lichens found. On the other rocks the lichens are much more mixed and there seems to be good evidence of the accepted succession for lichens: first the crustose; then the more foliose forms like *Lecanora rubina* and *L. rubina opaca;* and finally *Parmelia conspersa.* On the mesa, where the rocks range from 5^{dm} in diameter to coarse gravel, *Parmelia conspersa* is the most important lichen, although *Rinodina oreina* and *Lecanora calcarea* are also common. *Placo-*

dium elegans, which is also common on rock, seems to require protection and is probably one of the later species to appear. The same may be said of *Lecanora subfusca allophana*, one of the important lichens, which succeeds best in crevices.

The rock lichens occurring within this region belong to the primitive lichen formation.

FACIES: Parmelia conspersa (Ehrh.) Ach., Rinodina oreina (Ach.) Mass.

PRINCIPAL SPECIES: Lecanora calcarea (L.) Sommerf., L. subfusca allophana Ach., L. previgna (Ach.) Nyl., L. rubina (Vill.) Ach., L. rubina opaca Ach., Placodium elegans (Link) DC., Buellia petraea montagnaei Tuck., Lecanora previgna revertens Tuck., L. xanthophana dealbata Tuck., Staurothele umbrina (Wahl.) Tuck.

SECONDARY SPECIES: Placodium cerinum (Hedw.) Naeg. & Hepp., Acerospora chlorophana (Wahl.) Ach., Biatora crenata dealbata Tuck., Heppia Despreauxii (Mont.) Tuck., Placodium vitellinum (Ehrb.) Naeg. & Hepp., Umbilicaria rugifera.

This formation occurs on all exposed rocks, with the possible exception of the Permian, which in most places disintegrates too rapidly to support a lichen flora. With the exception of the last four species, all of the species occur on exposed surfaces. The last four and *Placodium elegans* prefer shaded or at least somewhat protected situations. Throughout the mesa this formation has been almost completely replaced by the Bouteloua formation. On hills and more exposed rocky situations it is sometimes as important as the grass formation with which it alternates. With the more complete disintegration of the rocks this formation will entirely disappear.

On alluvium.

Uncertain as is our knowledge of the primary succession on rock, it is much more certain than our knowledge of the primary succession on alluvium. A careful study of the formation, and in particular those places which are least covered with vegetation, seems to aid in forming an idea of this primary succession.

Near Eastonville, in the region lying between the Bouteloua formation and the invading pine formation, an open area is being invaded by the following species: *Potentilla coloradensis*, *Thermopsis rhombifolia*, *Erigeron glandulosa*, *Paronychia Jamesii;* followed by *Arenaria Fendleri*, *Muhlenbergia gracilis*, *Bouteloua oliogostachya*,

Gutierrezia Sarothrae, Artemisia canadensis, and *Tetraneuris glabriuscula*. This is probably the best example of primary succession found by the writer. The absence of ruderal species is especially noticeable.

On the mesa the *Andropogon scoparius* consocies seems to be most primitive. In places not yet covered with vegetation, where the alluvium is nearest what it seems to have been originally, this grass is most abundant and together with *Eriocoma cuspidata* is the first to disappear in passing from this exceedingly open association to the more stable or closed Bouteloua formation. *Eriognum alatum, E. Jamesii, Tetraneuris glabriuscula*, and *Machaeranthera cichoracea* are generally present; but since they extend into the true Bouteloua formation they are probably not as much a part of the primitive association as the plants mentioned above.

The lime ridge vegetation is probably primitive, as shown by the following quadrat:

Lesquerella alpina	52	Oreocarya thyrsiflora	3
Gutierrezia Sarothrae	5	Gaura coccinea	1
Lithospermum linearis	4	Machaeranthera cichoracea	1

Total surface covered, 5 to 6 %.

At some distance from this, a quadrat shows the following:

Lesquerella alpina	31	Eriogonum Jamesii	3
Grindelia squarrosa	14	Boebera papposa	3
Hedeoma nana	13	Lithospermum linearis	1
Gaura coccinea	8	Salsola Tragus	2
Bouteloua oligostachya	6	Eurotia lanata	1
Aristida longiseta	4	Machaeranthera cichoracea	1
Stipa Vaseyi	3		

Total surface covered, 7 to 8%.

The entrance of Bouteloua is already noted, as is *Aristida longiseta*. A more distant point will show the following quadrat:

Bouteloua oligostachya	54	Lithospermum linearis	6
Atheropogon curtipendulus	28	Aristida longiseta	3
Grindelia squarrosa	16	Eriogonum Jamesii	2
Boebera papposa	57	Pentstemon angustifolius	1
Malvastrum coccineum	7	Salvia linearis	2
Lesquerella alpina	6	Stipa Vaseyi	1
Helianthus annuus	8	Salsola Tragus	2
Gutierrezia Sarothrae	13	Artemisia frigida	3
Chenopodium leptophyllum	10	Evolvulus pilosa	1

Total surface covered, 18 to 20%.

These quadrats are all on steep slopes where the soil is more or less broken. The first quadrat is in pure disintegrated limestone; some gravel has been washed into the second quadrat; while the third is a mixture of gravel, clay, and lime. The difference in soil is of no importance in this connection, since in other places the same succession occurs on the pure disintegrated limestone. In the first quadrat the water content varies from 19 to 6%; in quadrat 3 it varies from 19 to 2%; while in the second quadrat the per cent. of water is intermediate. As one passes from the first quadrat to the second and then to the third, the facies of the Bouteloua formation are found making their appearance; in fact, the flora, aside from a few ruderal species and *Lesquerella alpina*, is decidedly of the Bouteloua formation.

The native species, which are referred to as ruderal, show the greatest ability to occupy new ground and they are the most important in secondary succession. It seems reasonable to suppose that they were also very active in invading the newly formed alluvium, and that, if any of the existing species have taken part in the primary succession, these plants are to be sought among the native ruderals. This can be more clearly understood after a consideration of secondary succession.

SECONDARY SUCCESSION.

The repeated changes which have taken place in the formation of the great plains have manifestly been accompanied by changes in vegetation. What these changes have been can only be inferred from the changes which are now taking place wherever, in the process of erosion, there is a cutting away or deposition of material. These successions in a certain sense are primary, but will be discussed under secondary successions.

Biotic agencies.

There are so many chances for observing secondary successions that the experimental denuded quadrat was not deemed necessary, although several of these are now under observation. There are many trails which lead through the Bouteloua formation where the ground has been but slightly disturbed (*fig. 12*). The travel has simply worn off and killed the original vegetation. After having

been in use for a longer or shorter time they are generally abandoned. The soil is hard, in fact has never been broken, but since there is no vegetation, an opportunity is afforded for the entrance of new plants. These trails have not been used in wet weather, and they are therefore never cut up and no loose soil is formed. The succession here is first ruderals like *Boebera papposa*, *Amaranthus blitoides*, or *Verbena bracteosa*. These seem to be most successful

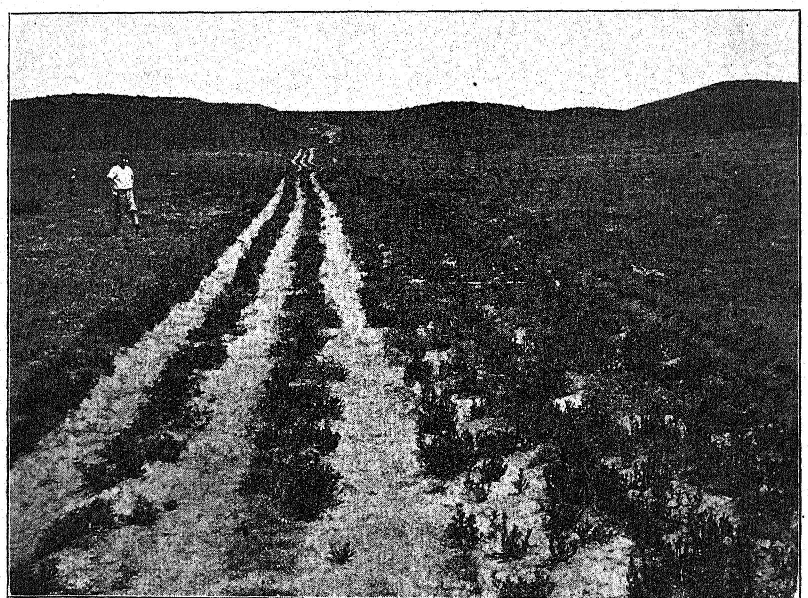

FIG. 12.—Trail invaded by *Boebera papposa;* Bouteloua formation at the sides.

invaders of such trails. The grasses of the formation come in slowly, *Muhlenbergia gracillima* generally in advance of, or with *Schedonnardus paniculatus*, *Sitanion elymoides*, *Athero pogon curtipendulus*, and ultimately *Bouteloua oligostachya*. It is not an uncommon thing to find these old trails only distinguishable by the depression of surface and completely covered by the *Muhlenbergia gracillima* consocies. Where the same trail leads through the purer growth of *Bouteloua oligostachya*, it is not so rapidly covered, and when it passes through the *Bouteloua hirsuta* consocies it remains open for a still longer period.

The mesa road was originally of the type just mentioned. During wet weather the road would be cut up to a certain extent and drivers would then turn to one side in order to escape the rough road. The new path has always been formed on the southwest side. This road has been in constant use for several years with the result that plants have been destroyed continually on one side, and have invaded the old roadways from the other. These old roadways show a great many stages in succession.

The road is left in a somewhat roughened condition and the most important species to enter is *Stipa Vaseyi.* It thrives best in newer situations and disappears gradually as one passes back from the well-formed frontal zone. The stable condition which it brings about is not favorable for the growth of the seedlings and it dies out after ten to fifteen years. Aside from the entrance of the annual ruderals *Boebera papposa*, *Amaranthus blitoides*, and *Verbena bracteosa*, it represents the first stage in the succession which will result ultimately in the *Bouteloua oligostachya* formation.

The species which ultimately take possession are usually determined by the adjacent formation. Where *Muhlenbergia gracillima* is dominant it usually appears much in advance of *Bouteloua oligostachya*; but where the latter is dominant, it is usually in advance. *Stipa Vaseyi*, the first perennial to appear, is usually accompanied by the annuals *Boebera papposa*, *Salvia lanceolata*, *Polygonum aviculare*, *Amaranthus blitoides*, and a number of other species. The grasses enter in about the following order: *Schedonnardus paniculatus* followed by *Sitanion elymoides* and *Aristida longiseta*, and ultimately by *Muhlenbergia gracillima* and *Bouteloua oligostachya*. With these grasses there appear many annual ruderals and also the following: *Senecio spartioides*, *Gutierrezia Sarothrae*, *Artemisia frigida*, *Carduus undulatus*, *C. plattensis*, and *Pentstemon angustifolius*.

A transect of the mesa road will give more detailed information regarding the sucessions found here (see transect). This transect is one meter wide. In the plot each division represents one meter, and the most important species in each square meter is placed at the left, and the other species in order of their importance are added to the right.

Bouteloua Formation	Bo	M		B	G					S		
	Bo	M	B		Af		G					
	Bo	B	M		Af		G					
Old roadways — the oldest near the top	Bo	M	Sv	B	Af	Sl	G	Ss				
	SP	M	B	Sv	Bo	Af	G	Cu		Sl	Ss	
	M		Bo	B	Sv	SP	Ad	Af	Va	Cl		
	SP	Sv	Ss	G	B	Sl	Cu	Mc				
	SP	G	Ss	Ad	Af	Mc	Cu	So		Va		
	SP	Sv	Bo	G	B	Sl	Al	Cu				
	Bo				Sv	B	Sl	G	Y	M		
	Bo	Sv	Sl	Ss	Cl			Al				
	Sl	B	Sv	Ss	SP	M			St	So	Str	
	B	SP	Sv	Sl	Vb		Se	Pa	St	S	Ss	Te
	B	SP	Sv	M		Sl	Mc	Cl	G	S	Va	Pa C Sc
	Sv	Se	B	Cl	Sl		Pa			C		
	Sv		Se	B	Sl		Ss	Ad	Af	Va	Cl	
	SP	Sy	B	Sl	So	Ad	G	Cl	Ss	Va	S	
	Sv	B	Bo	SP	Se	Cl		Sl				
	B	Sp	Sv	Cl	Va	Sl	L	Pa	Te			
	B	Sp	Sv	Cl	Va	Ad						
	B	Sv	Cl	Sp		Sl	Ss					
	B	Sv	Aa			Sp	Sl	Y	Pa	S	Se	
	Sv	B	Sl							Va		
	Sv	B	Sl			St	Sc	Ab	Ca	I	Pa	
ROAD												
								B				
						B		Aa				
			B	Aa			Ss					
			B			S	Ss	Aa				
	B	Bo				Mc						
Bouteloua Formation	Bo		B			S	G	Ss				
	Bo		B			Y	Ss	Tg	Te			
	Bo	B			Y	Sp		G	S			
	Bo	Tg	B	Al	M	Ad	G	S	Ee			
	Bo	A	M	L	B	S	Ad	Tg	Te	Ee		
	Bo		M	G	Bh	A	B	Ss	S			

A, Atheropogon curtipendulus
Aa, Atriplex argentea
Ab, Amaranthus blitoides
Ad, Astragalus Drummondii
Af, Artemisia frigida
Al, Aristida longiseta
B, Boebera papposa
Bh, Bouteloua hirsuta
Bo, Bouteloua oligostachya
C, Calamovilfa longifolia
Ca, Cycloloma atriplicifolium
Cl, Chenopodium lepidophyllum
Cu, Carduus undulatus
Ee, Eriogonum effusum
G, Gutierrezia Sarothrae
I, Iva xanthifolia
L, Lappula occidentalis
Mc, Malvastrum coccineum
Pa, Polygonum aviculare
S, Sideranthus spinulosus
Sc, Sporobolus cryptandrus
Se, Sitanion elymoides
Sl, Salvia linearis
So, Senecio oblanceolatus
Sp, Schedonnardus paniculatus
Ss, Senecio spartioides
St, Salsola Tragus
Str, Solanum triflorum
Sv, Stipa Vaseyi
Te, Townsendia exscapa
Tg, Tetraneuris glabriuscula
Va, Vicia americana
Vb, Verbena bracteosa
Y, Yucca glauca

TRANSECT OF MESA ROAD.

This transect is typical of the greater part of the road. Near Gleneyrie *Machaeranthera cichoracea* appears in abundance in the frontal zone. At the lower end of the mesa road is found considerable variation. *Cleome serrulata* forms the frontal zone, and with this *Boebera papposa*, *Xanthium commune*, *Polygonum aviculare*, *Verbena bracteosa*, *Munroa squarrosa*, *Amaranthus blitoides*, *Solanum rostratum*, *Chenopodium album*, and *Malvastrum coccineum*. Just back of this, on a portion of the old roadway, is *Stipa Vaseyi*, with *Boebera papposa*, *Euphorbia dentata*, *Chenopodium leptophyllum*, *Ambrosia artemisifolia*, *Sophora sericea*, *Polygonum aviculare*, *Schedonnardus paniculatus*, *Bouteloua oligostachya*, *Muhlenbergia gracillima*, *Artemisia frigida*, *Xanthium commune*, *Carduus undulatus*, *Iva xanthifolia*, *Asclepias pumila*, and *Salvia lanceolata*. The advance on the graded graveled part is made almost entirely by annuals, *Boebera papposa*, *Verbena bracteosa*, *Amaranthus blitoides*, or in rare cases *Solanum rostratum* is most important, while other species are generally present in reduced numbers. The soil in these cases has been packed down and *Stipa Vaseyi* does not enter.

The old mesa road is not followed by the new in all places. In the lower end of the mesa it turns to one side. Here through the original formation, it was only a path. It had been worn down and when abandoned the soil, through the agency of frost and rain, had loosened and fallen in at the sides. This road is now revegetated with *Stipa Vaseyi*, which is in many places replaced by *Muhlenbergia gracillima* and *Bouteloua oligostachya*. In one place this vegetation is practically identical with the formation.

The successions on trails vary considerably in different parts of the region. As one travels from Colorado Springs to Palmer Lake changes are soon noted. A short distance above Colorado Springs *Boebera papposa* becomes less abundant and the first species to invade the roadway is *Plantago Purshii*. Above Monument *Stipa Vaseyi* drops out as an invader, and the principal species which enter are *Polygonum aviculare*, *Lappula occidentalis*, *Verbena bracteosa*, *Amaranthus blitoides*, *A. retroflexus*, *Salvia lanceolata*, and *Rumex acetosella*. Below Monument a short distance the following succession was noted: The advancing zone was made up of *Lepidium*

apetalum, Polygonum aviculare, Artemisia frigida, A. canadensis, Verbena bracteosa, and *Plantago Purshii;* while farther back were found *Bouteloua oligostachya, Schedonnardus paniculatus, Chrysopsis villosa, Arenaria Fendleri, Gilia aggregata, G. pinnatifida, Senecio oblanceolatus, Gutierrezia Sarothrae, Koeleria cristata*, and *Sitanion elymoides;* followed by the Bouteloua formation in which *Bouteloua oligostachya, Stipa comata*, and *Arenaria Fendleri* were most important.

The stages of a succession which converts a denuded trail into the Bouteloua formation are not marked. First there is, as a rule, the entry of many annual ruderal species (*fig 12*). This in many cases is followed by *Stipa Vaseyi*, followed by *Schedonnardus paniculatus, Sitanion elymoides*, and *Aristida longiseta*, as well as many other secondary species of the formation, and these in turn by the facies of the grass formation. In some places *Stipa Vaseyi* does not enter and here may be found many other species. Among the more important are *Schedonnardus paniculatus, Gutierrezia Sarothrae, Chrysopsis villosa, Artemisia frigida, A. canadensis*, and many other species, followed by the facies of the grass formation.

Near Cheyenne Mountain a number of abandoned corrals show the following as the most important invading species: *Schedonnardus paniculatus, Artemisia canadensis, Solidago* sp., *Artemisia frigida, A. gnaphalodes*, and a number of secondary species—*Petalostemon purpureus, Thelesperma gracile, Chrysopsis villosa, Pulsatilla hirsutissima, Lacinaria punctata, Sporobolus cryptandrus, Aristida longiseta, Bouteloua hirsuta, Aragallus Lambertii*, and the ruderals *Boebera papposa* and *Euphorbia glyptosperma.*

A denuded quadrat showed during the third summer *Artemisia canadensis, Geranium caespitosum, Pulsatilla hirsutissima, Chrysopsis villosa*, and *Artemisia ludoviciana.* A second corral showed *Artemisia canadensis* and *A. frigida* as the chief invaders, with many other species coming in, of which those most important are *Schedonnardus paniculatus, Bouteloua oligostachya*, and *Koeleria cristata.*

The early stages of these successions vary greatly. In the study of a large number the following plants are found to enter first: *Boebera papposa*, in the mesa region and adjacent areas; northward toward Palmer Lake, *Plantago Purshii* or *Polygonum aviculare;*

and farther east *Picradeniospsis oppositifolia*, sometimes accompanied by *Malvastrum coccineum.*

A number of graded roads have been built very recently and these show only the very first vegetation, a ruderal annual vegetation. The boulevard, which runs from Colorado Springs to Manitou, is an older road of this type, having been built for about thirteen or fourteen years. The first permanent succession on this road within the Bouteloua formation was *Stipa Vaseyi*, which is now giving way to *Muhlenbergia gracillima* and *Bouteloua oligostachya.* Many other species came in, among which the more important are *Sitanion elymoides*, *Aristida longiseta*, *Schedonnardus paniculatus*, *Helianthus annuus*, *Quincula lobata*, *Astragalus bisulcatus*, *Sophora sericea*, *Grindelia squarrosa*, with other plants from the formation, as well as ruderal species.

One of the transects of this road deserves special mention. There is a cut here of about 2^{m}, and the road runs north and south. The differences in the east and west sides are due entirely to the differences in exposure, and to its effect upon temperature and water content. The west side, which receives the most light, has first a distinct zone of *Petalostemon oligophyllus*, back of which there is a mixed zone of *Boebera papposa* and *Xanthium commune;* this is followed on the bank by *Stipa Vaseyi*, and this in turn by a crest zone largely of annuals. The east side shows first a zone of *Xanthium commune* followed by *Stipa Vaseyi*, mixed with *Schedonnardus paniculatus*, *Boebera papposa*, *Psoralea tenuiflora*, etc.; and this is followed on the steep unstable soil by annuals. Back of the annuals is the Bouteloua formation in which *Muhlenbergia gracillima* predominates.

There is a great deal of variation in the species which first appear. Almost any one of the species cited under the ruderal formation may dominate in certain places, but the more or less typical examples mentioned above should serve to give an idea of the succession on roads.

Reservoirs are generally built where only one side needs to be dammed. The outer slope of the dam is invaded in the same way a road would be. An interesting exception is found at Palmer's reservoirs. The large reservoir, which was built in 1902, had by

1904 covered the bank chiefly with *Stanleya glauca* and *Mentzelia decapetala*. A great deal of the soil of this bank was hauled in from the lime ridge region, and with it, the seeds of *Stanleya glauca* were carried in. In one of the other reservoirs, which is several years older, *Medicago sativa* was predominant. Normally, *Boebera papposa*, *Stipa Vaseyi*, and other ruderals would be expected to appear first.

A new reservoir constructed on the mesa in 1904 showed during 1905 the following species: *Boebera papposa*, *Salsola Tragus*, *Senecio spartioides*, *Artemisia frigida*, *Senecio oblanceolatus*, *Argemone intermedia*, *Mentzelia nuda*, *Polygonum aviculare*, *P. Douglasii*, *Euphorbia robusta*, *Yucca glauca*, *Chenopodium album*, *Gaura coccinea*, *Cleome serrulata*, *Petalostemon purpureus*, *Amaranthus blitiodes*, and *A. retroflexus*.

In building roads and reservoirs it often happens that several meters of surface soil and all the vegetation is removed. Succession is different here from the places already mentioned. The annual ruderals do not appear in such great numbers. Among the species which enter are *Argemone intermedia*, *Mentzelia ornata*, *Petalostemon oligophyllus*, *P. purpureus*, *Sitanion elymoides*, *Aristida longiseta*, *Munroa squarrosa*, and other common hillside plants, since the soil here is usually gravel.

Broken areas.

Here and there on the plains are found areas which have been plowed and planted, but have been abandoned because of the scanty water supply. The succession of plants here is much the same as on graded roads, but is usually more uniform. An abandoned garden patch showed the following year the facies *Anogra albicaulis*, with *Chenopodium album* and *Helianthus annuus* as the principal species. An area on top of the mesa showed almost a pure stand of *Boebera papposa;* while still another showed *Schedonnardus paniculatus*. *Artemisia frigida* sometimes enters denuded areas and dominates the early stages of the succession. During 1904 a tract was seeded with *Lolium perenne;* the following summer it showed *Boebera papposa* and *Verbena bracteosa*, as well as *Polygonum aviculare*, *Salsola Tragus*, *Artemisia frigida*, *Lolium perenne*,

Solanum triflorum, *Senecio oblanceolatus*, and *S. spartioides;* also a very few young plants of *Yucca glauca*, *Argemone intermedia*, *Carduus undulatus*, and *Tetraneuris glabriuscula*.

The usual flora on the hills of the prairie dog is *Anogra coronopifolia*, *Malvastrum coccineum*, *Munroa squarrosa*, *Amaranthus blitoides*, *Picradeniopsis oppositifolia*, *Boebera papposa*, and *Artemisia frigida*. *Muhlenbergia gracillima* is the most effective in reclaiming the old deserted hills. In fact, in looking over a deserted dog town the location of the old dog hills can be determined at once from the fact that although the surrounding vegetation is dominated by *Bouteloua oligostachya*, the location of the old hills is marked by a community of *Muhlenbergia gracillima*.

Near Pring, Colo., an abandoned field showed the first year *Helianthus petiolaris*, with a less amount of *Boebera papposa*, *Malvastrum coccineum*, *Solanum rostratum*, *Lappula occidentalis*, *Verbena bracteosa*, and a very few plants of *Artemisa frigida*, *Atheropogon curtipendulus*, *Schedonnardus paniculatus*, *Carduus undulatus*, and *Eriogonum annuum*. Here are found three very distinct sets in the succession. First, annual species, followed by a group of ruderal species, and this in turn by perennials from the Bouteloua formation. In another place *Thelesperma intermedium* was the first species to enter. Near Falcon, Col., an abandoned field showed after two years *Helianthus petiolaris* and also *Munroa squarrosa*, *Lappula occidentalis*, *Chaetochloa viridis*, *Plantago Purshii*, *Amaranthus retroflexus*, and *Ptiloria ramosa*. In some places *Bouteloua oligostachya* was entering. Another field which had been abandoned for about eight years showed *Sporobolus cryptandrus*, *Aristida longiseta*, *Schedonnardus paniculatus*, *Cenchrus tribuloides*, as well as *Senecio oblanceolatus* and *Munroa squarrosa*, a few annuals, the more important of which were *Helianthus petiolaris*, *Verbena bracteosa*, and *Cryptanthe ramosissima*. Into this area *Bouteloua oligostachya* was pushing its way and had in places near the edge of the field almost replaced the other species.

Several miles west and south of Fountain, Col., a most interesting stage of succession is shown. The surrounding vegetation is of the *Bouteloua oligostachya* consocies with very few primary and secondary species. An area which had been broken and abandoned showed

the *Muhlenbergia gracillima* consocies almost entirely replacing the earlier stages of the succession. A very little *Boebera papposa* and *Schedonnardus paniculatus* remained, while about an equal amount of *Bouteloua oligostachya* was invading and will after a number of years replace the Muhlenbergia.

As long as the ants are alive, they remove all vegetation for some distance around their hills. In low places *Cleome serrulata* may form a semicircular zone on the lower side of this denunded area. *Helianthus annuus*, *H. petiolaris*, *Stipa Vaseyi*, and many other species may also be found in this situation. The most common plant to develop in this area is *Munroa squarrosa*, which often forms a perfect zone.

Erosion.

The dry soil is easily washed away by heavy rains. This forms loose soil at the base of the hills and also leaves broken places from which the soil is removed. On the hillsides there are often produced natural terraces, each of which ends in a broken edge. During the rains these terraces are cut back and new soil is exposed. These places may be occupied by *Boebera papposa*, *Salsola Tragus*, or other annuals, but generally *Stipa Vaseyi* is the invading species. Here it serves to bind the soil and prepare the way for *Muhlenbergia gracillima* and *Bouteloua oligostachya*.

In the low draws there is generally a hollow washed out below the terrace, and as a result of the falling in of the soil when dry there is found both loose and undisturbed soil. These places are marked by a growth of *Stipa Vaseyi*, with *Boebera papposa*, *Solanum rostratum*, and often *Salvia lanceolata*, *Helianthus annuus*, *Verbena bracteosa*, *Salsola Tragus*, *Xanthium commune*, and *Leptilon canadense*. Places such as this are very much like the ordinary draw where more or less of the soil which was washed down from the hills is deposited. Conditions here are also almost the same as in the alluvial fans which are formed at the bases of all the ravines, whether they be small or large. Here new soil is deposited during every heavy rain, and as a result the slow growing grasses such as *Bouteloua oligostachya* and *Muhlenbergia gracillima* cannot thrive. *Stipa Vaseyi* is the most successful plant of such habitats. It marks the

dry water courses and also all of the alluvial fans. Succession here is practically the same as on any ruderal area. In addition to *Stipa Vaseyi* there is usually found *Boebera papposa*, *Salvia lanceolata*, and in some cases *Xanthium commune* and *Cleome serrulata*. When the soil has become more stable *Stipa Vaseyi* slowly gives way. *Artemisia frigida* is now one of the first species to appear, and is often dominant after *Stipa Vaseyi* has disappeared entirely. This

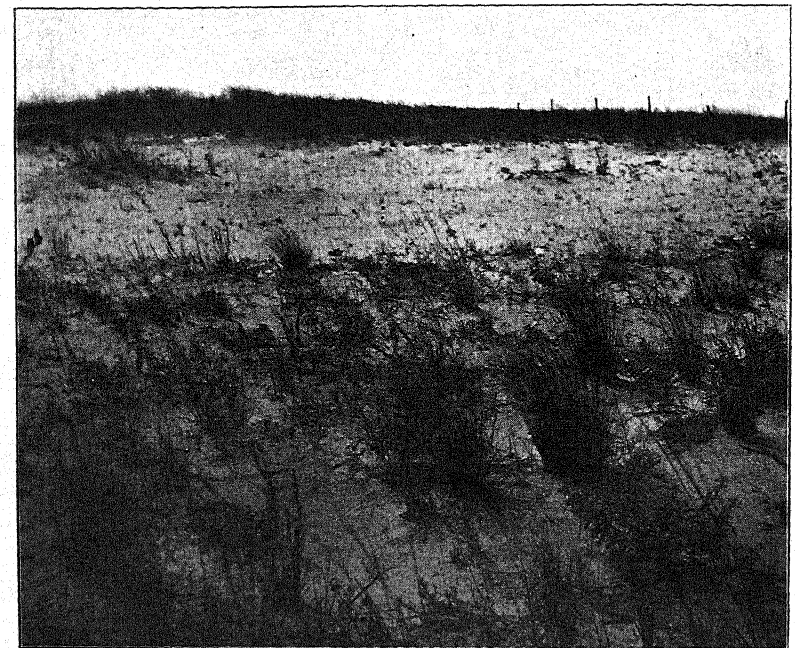

FIG. 13.—Blow-out; the prominent plants are *Muhlenbergia gracilis*, *Meriolix serrulata*, *Artemisia canadensis*, and *Andropogon scoparius*; *Calamovilfa longifolia* in the background.

is followed by *Muhlenbergia gracillima*, and after a number of years this is replaced in turn by *Bouteloua oligostachya*.

On dry sandy ridges blow-outs are often found (*fig. 13*). The succession here is usually *Polygonella articulata*, *Cycloloma atriplicifolium*, *Carex* sp., *Muhlenbergia gracilis*, *Sporobolus cryptandrus*, *Artemisia canadensis*, *Thelesperma gracile*, *Eriogonum annuum*, *Meriolix serrulata*, *Chrysopsis villosa*, and *Andropogon scoparius*.

The most important plant occupying the alluvium deposited by permanent streams is *Melilotus alba.* Species of minor importance are *Juncus bufonius* and *Riccia crystallina.*

ANOMALOUS SUCCESSION.

When biotic or physical agencies bring about sufficient change in the habitat, the result is an anomalous succession. The change of habitat may be gradual and yet the effect on the succession be such as will change entirely the ultimate formation. We may also have the succession interfered with in such a way as to hasten the ultimate formation, to cause it to become more stable in a shorter time, or to retard the succession or reduce it to a more primitive condition.

Due to grazing.

The influence of grazing is very clearly seen by comparing fenced areas with those that have not been protected from grazing animals. Cattle, and to a less extent horses, are the only animals that have grazed within this region in recent years.

Near the lower end of the mesa is Colorado City, the old territorial capital of Colorado and known as one of the oldest towns in the state. For fifty years it has been the custom to have a herd boy drive the cattle out on the adjacent areas to graze each day and bring them back each night. Colorado Springs, a more recent city, also sends its herds out on the same area. It will be well, at first, to see what effect this has had upon the Bouteloua formation. In those parts of the formation where grazing has not played a part the formation is very open, while in the grazed portions it is more closed. In the open formations many species appear with the grasses, while in the more closed formation these species are almost entirely absent. A typical quadrat from the south mesa which has been grazed shows the following species:

Muhlenbergia gracillima	23	33%	Sideranthus spinulosus	3
Bouteloua oligostachya	24	12	Malvastrum coccineum	5
Atheropogon curtipendulus	1		Townsendia exscapa	2
Artemisia frigida	2		Echinocereus viridiflorus	1
Boebera papposa	36			

Total surface covered, 45 to 50%.

In some of the draws the preponderance of *Muhlenbergia gracillima* is even more marked. Near the above quadrat, in a portion protected from grazing, a quadrat would show:

Bouteloua oligostachya	18 %	Artemisia frigida	1
Muhlenbergia gracillima	2.5	Artemisia gnaphalodes	1
Aristida longiseta	2.5	Gutierrezia Sarothrae	2
Chrysopsis villosa	8	Sitanion elymoides	1
Thelesperma gracile	9	Eriogonum alatum	2
Echinocereus viridiflorus	4	Pentstemon angustifolius	1
Opuntia polyacantha	3	Carex pennsylvanica	5
Euphorbia robusta	1		

Total surface covered, 27%.

In a portion of the mesa which has been grazed, but not to such an extent as the first quadrat given, is found:

Bouteloua oligostachya	22%	Artemisia frigida	5%
Muhlenbergia gracillima	7		

It cannot be stated positively that this condition is entirely due to grazing. It seems likely, however, that grazing would favor the development of grasses and tend to destroy the other plants, particularly the dicotyledons. There is a very noticeable difference in adjacent areas when one is protected from grazing. The preponderance of *Bouteloua oligostachya* and *Muhlenbergia gracillima*, and the paucity of higher spermatophytes in the grazed area is the chief difference. This seems to be the exact condition which would come about by natural succession and the grazing in this case hastens this succession. The more primitive parts of the formation and those which have not been grazed are much alike. Grazing, when not too severe, favors the development of the facies of the formation.

Still another condition due to grazing should be considered. Near Colorado City, and particularly in the region lying between Colorado City and Colorado Springs, the grazing has been very severe. The result here has been first to drive out most plants other than the grasses, and ultimately even to destroy *Bouteloua oligostachya* and *Muhlenbergia gracillima* to a great extent. A few plants, such as *Astragalus bisulcatus*, *Chrysothamnus graveolens*, *Grindelia squarrosa*, and others which are not touched by grazing animals, still survive; but the character, aside from a few of these species, is now almost entirely marked by annuals. The succession has

become practically that which follows on a denuded area. *Salvia linearis*, *Atriplex argentea*, and *Bouteloua prostrata* are here the principal species. With these are found many of the ruderal plants as well as the following important perennials: *Agropyron occidentale*, *Astragalus bisulcatus*, *Sophora sericea*, *Vicia americana*, and a very little *Bouteloua oligostachya*, *Quincula lobata*, and *Phyllopterus montanus*.

The effect is to delay the succession or to cause it to return to a more primitive condition. The grazing does not change the Bouteloua formation into another formation, since grasses seem to be especially adapted to these conditions.

The effect of grazing is very different on the thicket formation. Wherever cattle are allowed to crop the thicket formation very closely, the facies are completely killed. This is the most noticeable in the case of the oaks, which are killed by the entire loss of chlorenchyma tissue. They are attacked by cattle before any of the other facies of the thicket formation.

An examination of the region shows that on the mesa near Colorado City the thicket formation has been replaced almost entirely by the Bouteloua formation. Only scattered bushes of *Cercocarpus parvifolius* and *Rhus trilobata* are found and these much reduced in size. The explanation lies in the fact that this portion has been grazed more than the part which is farther removed from Colorado City. The remnant of the old thicket can be seen in many places, and the stages in the succession which have produced a grass formation instead of a thicket formation may be traced. There is a scanty plant growth under these shrubs. When they are killed outright the space is open to plant invasion, and as a result the ruderals come in in abundance. *Chenopodium album* may be one of the forms which appears at this time, especially if the cattle have destroyed most of the under vegetation. At other places where the shrubs have been cut down the succession may be much the same as the ruderal succession and result in the typical Bouteloua formation. As a rule the shrubs are gradually reduced in size. The result here is that the grasses slowly encroach upon the area as the shrubs are eaten lower, and as the clump becomes more open the undergrowth increases. *Agropyron occidentale*, *Stipa comata*, *S. neo-mexicana*, *Atheropogon curtipendulus* come in slowly; *Coleo-*

santhus umbellatus and *Chenopodium Fremontii* disappear. When the shrub ultimately dies and breaks up, there is a very small ruderal place in which the succession is identical with that already described for denuded places. Grazing changes the thicket formation to a grass formation, and the more rapid the change the more nearly it approaches the ordinary ruderal successions.

Due to drainage.

Drainage is not an important factor, but it seems best to consider here those changes which result when an irrigated area is left without irrigation, a ditch abandoned, or the water of a stream turned aside causing the bed to become dry.

Examples of the first case mentioned are not found excepting where, because of lack of attention, the water does not flow evenly over a meadow. The succession here is gradual, forms like *Erigeron flagellaris*, *Vicia americana*, and *Astragalus hypoglottis* taking the place of the more hydrophytic grasses and rushes. If the change of habitat is abrupt, most of the species die and a ruderal succession follows. When the change is very gradual, the species mentioned above, together with *Agropyron occidentale*, take the place of the rushes. *Bouteloua oligostachya* often appears in this stage of the succession, but *Muhlenbergia gracillima* is one of the last to appear.

In abandoned ditches a mixed formation is generally found. In this habitat the following species of the mesophytic bank formation may continue for a long time: *Clematis ligusticifolia*, *Xanthium commune*, *Symphoricarpos occidentale*, *Stachys palustris*, *Erigeron flagellaris*, and *Vicia americana*. The last two species are elements of the Bouteloua formation and are able to adapt themselves to the change of habitat. Of the grasses of the Bouteloua formation, *Bouteloua oligostachya* and *Agropyron occidentale* are the first to enter. They appear much earlier than *Muhlenbergia gracillima*, and thrive even better in these transformed ditches than in the Bouteloua formation proper.

There is only one example of the effect of a change in the natural water course. This is not complete, but enough water has been taken from Camp Creek to cause it to be dry for a greater part of the year. The first and most noticeable effect has been the death of

the trees, *Populus angustifolia* and *P. deltoides*. This condition has obtained for only about three years, and the effect thus far has been destructive. The bank species, with the exception of those that are able to exist in more xerophytic habitat, have died, and aside from the entrance of a very few ruderals there has been no marked succession as yet.

Due to irrigation.

The changes produced by irrigation are complete and varied. Where a ditch passes through the Bouteloua formation in places where there is seepage, the first stages of the succession which lead to the irrigated meadow formation are found. The effect here is usually the better development of *Agropyron occidentale*, and at the same time the disappearance of *Muhlenbergia gracillima*. *Bouteloua oligostachya* also grows more rank than where not irrigated. This succession is exceedingly variable, probably because of the variable water supply, and the stage of the succession is an index to the amount of water added. In some places the meadow flora is reduced largely to rushes and other hydrophytic plants, while in other places *Bouteloua oligostachya*, *Erigeron flagellaris*, *Vicia americana*, and *Astragalus hypoglottis* are most important.

In the bank formation the conditions are varied. Between the water and the xerophytic formation through which the stream or ditch runs, there are all gradations from hydrophytic to xerophytic. But to divide this formation in regard to water content of the soil would not be practicable. Another condition makes the formation more complex. In the ditch formation, there is, besides the invasion of the mesophytic and hydrophytic plants, the entrance of the ruderal. When the ditch is first made the ruderal formation makes its appearance. At almost the same time the mesophytes and hydrophytes appear. The ruderal formation always tends towards self destruction. Here the result is that the outer portion of the ditch is ultimately occupied by the characteristic Bouteloua formation, while on the inner the more mesophytic bank species become established. In the ultimate bank formation the line of separation from the grass formation is very distinct.

Along many of the irrigation ditches a condition prevails which

prevents the development of the ultimate stage of the succession. Each year the bottom of the ditch fills up with silt which is removed to the bank the following spring. This forms a new soil for the entrance of ruderal species, and as a result the bank returns to a somewhat primitive condition.

Another factor of importance here is the fact that during the winter the ditch is empty the greater part of the time. This condition is detrimental to the success of the species of the ultimate formation. The result is that along these irrigation ditches are found various stages of anomalous successions, which are checked repeatedly, or even turned back by the reversion to more primitive conditions. The successions are interrupted again and again, and this may account to a great extent for the variable character of the bank formation.

General discussion.

After careful study it is at once apparent that all parts of the formation are not of the same age. The secondary successions throw much light upon the structure as well as upon the development of the formation. These exhibit rather well-marked stages. The first is a ruderal consocies; the second, a society of the formation; while the ultimate stage is a consocies of the formation. All of these successions lead undoubtedly to the Bouteloua formation.

The successive deposition and erosion which has produced the Great Plains does not differ markedly from that which may be noted at the present time. The vegetation on new deposits of soil passes through the typical succession leading from the ruderal to the grass formation. Near the mountains the cutting back of the gullies results in the establishment of the thicket formation, which is preceded usually by the entrance of many of the secondary species of the thicket and grass formation. The pine formation is usually mixed with the thicket formation. When this cutting back of the gullies exposes rocks of a sufficient degree of stability, the primitive lichen formation precedes all others.

In many places gullies are cut back which are reclaimed at once by the grass formation. The thicket and pine formations do not enter. In these places the *Andropogon scoparius* consocies usually becomes established.

The elevated dry ridges are occupied by the *Selaginella densa* formation in which *Paronychia Jamesii* is a prominent species. This evidently represents a younger stage in a succession which will give ultimately the Bouteloua formation. Among the most important invading species are *Stipa comata, Koeloeria cristata,* and *Bouteloua hirsuta*.

If these ridges are sandy, blow-outs often occur which result when reclaimed in the *Calamovilfa longifolia* consocies (*fig. 13*). This consocies thrives much better when not grazed. Grazing changes it to the Bouteloua consocies.

The *Andropogon scoparius* evidently represents an earlier stage in the formation than the *Andropogon furcatus* or *Bouteloua oligostachya* consocies. It occurs on the hillsides and also is found as an early stage in the succession on denuded xerophytic areas. The study of secondary succession would lead also to the belief that *Muhlenbergia gracillima* is only a stage, for here it is replaced repeatedly by *Bouteloua oligostachya*.

The societies of the formation are, without exception, dominated by species which are among the first to invade new areas. Their presence in the formation is largely due to historical reasons. To this may be added the fact that the consocies which represent the earlier stages, as for example the *Bouteloua hirsuta* consocies, have by far the greater number of societies.

The *Bouteloua oligostachya* consocies represents the ultimate stage of the grass formation and is by far the most widely distributed of any of the consocies of the formation.

This study of the Bouteloua formation was suggested by Professor Frederic E. Clements, under whose direction it has been carried on. To him and also to Professor Chas. E. Bessey the writer wishes to express his thanks for many helpful suggestions and criticisms. Thanks are also due to the following persons: Professor F. D. Heald, for advice and criticism; Professor Wm. Strieby, for generously giving me use of his laboratory for the determination of water content; and to Professor F. H. Loud, for meteorological data.

University of Missouri, Columbia.

CORTINARIUS AS A MYCORHIZA-PRODUCING FUNGUS[1]

C. H. KAUFFMAN.

(WITH ONE FIGURE)

THE study of the mycorhiza problems has received a new impetus during the last six years by the appearance of extensive papers by MACDOUGAL (1), STAHL (2), TUBEUF (3), HILTNER (4), and MÜLLER (5). Considerable evidence has been adduced showing that in the case of the endotrophic mycorhiza the organisms concerned act as purveyors of nitrogen to the symbiont or host with whose roots they are connected (6–7); furthermore, the organisms in some of these cases have been quite exhaustively studied (8–9). On the other hand, the fungi which cause the ectotrophic mycorhiza have not been investigated except in a very few cases.

It is a noticeable fact as one looks over the literature, that the larger part of the work hitherto attempted has been done on a basis of several unknown quantities. One of these is the identity of the fungus which causes the ectotrophic mycorhiza. The earlier writers speak of the fungus as if it were a single species or genus. It was thought for quite a time that the ectotrophic mycorhiza of European trees was due in all cases to the tubers or truffles. WORONIN (10), in 1885, showed that this cannot be true for Finland, where the tubers are not found, but where nevertheless the mycorhiza are abundant. KAMIENSKI (11) also found no truffles in the regions where he studied the mycorhiza of Monotropa. REES (12) was at first inclined to think that Elaphomyces was the cause of the mycorhiza of almost all the trees he examined; later, he himself found mycelium of mycorhiza which differed in structure from that of Elaphomyces.

The fungi whose fruiting forms have been definitely reported as belonging to mycorhizal mycelium are comparatively few. MACDOUGAL (1) gives a list of mycorhizal fungi whose identity has been reported. The list is as follows: Fusisporium, Eurotium, Pythium, Nectria, Celtidia, Elaphomyces, Geaster, Boletus, Tricholoma, Lactarius, and Cortinarius. Of the non-mycelioid forms

[1] Contribution 89 from the Botanical Department of the University of Michigan.

which are known, *Phytomyxa leguminosarum* and Frankia are of course the most prominent. It will be seen that the list is remarkably small, especially if we remember that only one or two species is referred to in each case. As we are only concerned with ectotrophic forms, the first four can be omitted in the discussion, and if we consider the evidence on which the symbiotic connection of the remainder is based, we find the actual list even smaller.

In the case of the Boleti, WORONIN (**10**), after declaring the tubers out of the question, says: "Vielleicht gehört die hiesige Mycorhiza einem anderen, ebenfalls unterirdischen Pilze an, dies will ich nicht bestreiten, bin aber vielmehr geneigt anzunehmen, dass die oben angeführten Boleten mit der Mycorhizen zusammenhängen." It seems that WORONIN himself was not very certain of the connection. Elaphomyces was very exhaustively studied by REES (**11**), who showed that it is undoubtedly connected with the pines in localities where the truffle occurs. Two species of Geaster, *G. fimbriatus* and *G. fornicatus*, were shown by NOACK (**13**) to be attached to the roots of the spruce and pine.

When we come to a consideration of the agarics our knowledge is meager indeed. Only one investigator, NOACK (**13**), in 1889, has concerned himself with them. He found that five species of this group were apparently mycorhiza-producers on the forest trees of the locality where he made his observations. Two were Tricholomas; one a Lactarius; and three were Cortinarii. He merely makes the bare statement that they are connected with the rootlets by their mycelial strands, which he could easily make out. It is very probable that his observations are correct.

It seems to be appreciated that we need some investigation to determine what fungus we are dealing with, so that problems which have to do with the physiological side of mycorhiza may be undertaken more intelligently; for it is just as likely that knowledge concerning the fungus and its life history may lead to an understanding of the relation of the two organisms as a knowledge of the tree would. It seemed worth while, therefore, to report the identity of any such mycorhizal fungi whenever the evidence seemed sufficient to make it acceptable.

OBSERVATIONS ON **Cortinarius rubipes**, sp. nov.[2]

In a previous paper (14) I pointed out that the members of the genus Cortinarius were so constantly found in limited areas, and some species in such close proximity to certain trees, that it seemed likely that there was some connection. This last summer an effort was made to find out to what extent this might be true. The season was wet during the early summer, and although one finds few Cortinarii as a rule before August, several did occur, and one of

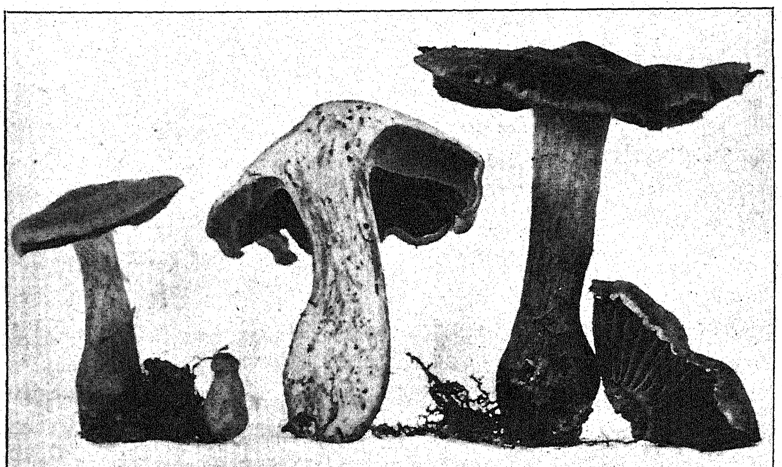

FIG. 1.—*Cortinarius rubipes*, sp. nov.—Left hand sporophores show the mass of rootlets and humus with strands of mycelium projecting above; right hand individual shows the roots with the short mycorhizal branches and the mycelial strands which are attached to the base of the stipe.—Photographed by the writer.

these proved to be favorable for my purpose. It not only showed beautifully its connection with the tree roots, but turned out to be an undescribed species of Cortinarius.

It was found July 4, 1905, on the south slope of a small ravine along the Huron River, near Ann Arbor, in a layer of humus and forest leaves. This species, as is indeed true of some other fleshy fungi, is characterized by its brick-red mycelial strands and stem. By removing the surface soil it was possible to see the brick-red strands intertwining with the rootlets apparently in all directions.

[2] For description in full, see 8th Report Mich. Acad. Sci. 1906.

But it was soon found that the reddish network extended along definite paths. Beginning with a tiny rootlet, the fungus was followed to a rather large root, apparently growing from a hickory. On examination, however, it was found that the mycorhiza-bearing root passed the hickory, and that all the roots of the hickory examined were devoid of a colored mycorhizal fungus. On the other hand, the root in question was now easily traced to a clump of red oaks, of second year growth, which were distant at least 54^{dm} from the starting point. Besides the hickory, the roots of a Crataegus which crossed the oak roots were likewise devoid of the fungus in question.

The red strands were attached only to the small rootlets, and where the roots extended below the black soil into the yellow subsoil the mycorhiza gradually disappeared, facts which were known to FRANK, STAHL, and others. The leaf mold along with the remains of last year's leaves forms a thin covering beneath which the young buttons of the fungus are started.

About twenty paces down the slope, another troop of the same species of Cortinarius was found. These came up only 30^{cm} away from a fine young sugar maple and close to one of its main roots. Expecting that they were probably attached to the roots of an oak a short distance away, I dug down carefully and found to my surprise that the strands which were very luxuriant here were attached to the rootlets of the sugar maple; even the small roots growing directly from the base of the trunk were thickly beset by the strands. The sporophores were loosened and the attachment of the strands followed from the stipe to the rootlets and thence to the tree. Several days later on visiting the same hill, two more sporophores were found on the north slope of the hill, again with the characteristic strands, and connected with a red oak.

I had to leave Ann Arbor at this time, and not until I came back in September did I have any further opportunity to make observations. On October 30 the slope was dug over for a considerable area around the original habitat of the Cortinarius in question. The roots of the same maple were found to be hung with the reddish strands in all directions, just as luxuriant apparently as in the early summer. Here, also, other roots crossing or intertwining with the maple roots—with one exception—were not affected by the fungus.

An ash, basswood, and white oak were examined, but no trace of the fungus found. About 27^{dm} from the sugar maple, it was found that some of the strands were apparently attached to a different root. Following this up to a clump of red oaks about 54^{dm} away, I was again surprised to find that the oak roots in this case were not connected with the fungus at all, but that the root which was followed —which did not have the appearance of an oak root—belonged to a large *Celastrus scandens* which wound around one of the oaks. It was clear that we had another symbiont connected with the fungus.

Discussion

It may be well here to call attention to the following points which have been brought out: (*a*) that *Cortinarius rubipes* (for so we will call it) is connected with three forest symbionts belonging to different families; (*b*) that it is apparently selective in the sense that the specific character of the symbiont does not necessarily attract it; (*c*) that one of the symbionts is a maple.

Noack (12), who has been the only investigator of the agarics as producers of mycorhiza, thinks he has connected *Tricholoma terreum* with both beech and fir, and *Lactarius piperatus* with beech and oak. My own observations seem to show that it is undoubtedly a fact that one fungus may be attached to trees of very different families. In the case of *Celastrus scandens* no fruit bodies were seen, but there can hardly be a doubt that it was the mycelium of the same species.

It is rather unexpected to find that the same tree species when exposed to the fungus does not always become associated with it. It is evident that the mycorhizal fungus may attach itself to very different hosts, dependent for its initial attachment on certain environmental factors.

The maples of Europe are reported as seldom forming mycorhiza (2). The roots of the sugar maple mentioned above were carefully examined with a lens, and also under the microscope, and mycorhiza seemed to be everywhere abundant on the smaller rootlets. How generally they occur on our maples is not known, as hardly any work has been done in this line in our country.

With regard to the kind of mycorhiza involved, there is of course

no uncertainty. Some of the strands and the connected rootlets were fixed and imbedded, and sections were made to determine the more intimate relations of the two organs. When stained rather deeply by fuchsin and gentian-violet the connection could be easily made out. It is clearly a true ectotrophic mycorhiza. There is a close-lying layer of parallel hyphae which surrounds the rootlet, and, in all but the youngest rootlets, branches of this layer penetrate the root and form a close intercellular tissue exactly as figured by FRANK (**13**). The cells of the root at this time seem to contain little protoplasm and occasionally hyphal threads are seen to cross the cells of the cortical layer farther in. In the youngest roots no intercellular tissue appears to be present.

It would seem that there must be some close physiological relation; FRANK indeed thought he had demonstrated it. At the present time, however, nothing definite is agreed upon. To attempt in some measure to solve this question, experiments are now under way with the mycelium of the above-mentioned mushroom. One fact may have some bearing on the problem; the species of the genus Cortinarius develop relatively slowly. The writer has never been able to bring buttons into the house and develop them there, as is possible with Amanitas and Volvaria. For some reason they seem to have lost the vigor necessary to this end. It may be that the explanation of this is found in that a part of their food supply is cut off, and that the tree really supplies some of the necessaries for the full development of the sporophore.

Let it not be supposed that all Cortinarii are mycorhiza-formers, at least normally. *Cortinarius armillatus*, for example, although very partial to *Tsuga canadensis*, is usually found among rotten logs or leaf-mold near this tree, and is probably a saprophyte; on the other hand, it has been found growing out of a cleft at the base of one of these hemlock trees. It seems quite likely, however, that a good many Cortinarii are in symbiotic connection in the manner of the one described in this paper. During several seasons' observations, I have found *C. squammulosus*, *C. bolaris*, and *C. cinnabarinus* again and again in places which would indicate some relation to one kind of tree. *C. cinnabarinus* seems to prefer the oak, the other two the beech. NOACK (**12**) has shown the connection of *Cortinarius callisteus*

with the beech, *C. caerulescens* with the beech, and *C. fulmineus* with the oak. Others will no doubt be added to the list as soon as observers enter this interesting field.

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A NEW FUNGUS OF ECONOMIC IMPORTANCE.

RALPH E. SMITH AND ELIZABETH H. SMITH.

(WITH THREE FIGURES)

AMONG the subjects of investigation by the California Agricultural Experiment Station, that of a destructive rotting of lemons occurring in southern California is one of the most important. The cause and means of control of this rot have been a complete mystery to the handlers of lemons, and the fact that the trouble has been found to be due to a fungus representing not only a new species, but a well-defined new genus, makes the case one of peculiar interest.

The rot in question has been called the "brown rot," distinguishing it from the "blue mould," or Penicillium rot, the commonest form of Citrus decay. The latter has been known since time immemorial, but with the best class of lemon shippers is not usually a great pest. Lemons affected by Penicillium are almost invariably those which have become bruised in handling or subjected to improper conditions. With fruit properly handled, cases of blue mould are only occasional. In these the affected lemon decays and becomes covered with the dusty fungus, finally collapsing into a slimy mass, without infecting the other fruit, even though they be covered with the spores. A Penicillium-affected lemon in the midst of a box does not usually infect the other fruit about it in the least when proper conditions are maintained.

Within the past few years a new and much more serious form of rot has been detected by the lemon growers and shippers. In lemons which had been picked, washed, and stored for curing, it was found that a rot developed which spread rapidly by contact through the fruit, soon involving the entire box if left undisturbed. In appearance the affected lemons are characteristic and easily distinguished from those affected by blue mould, though the latter fungus follows rapidly on the other and soon covers the decaying fruit. Particularly characteristic is the odor of lemons affected by brown rot, a peculiar rancid smell by which an experienced person can detect one affected lemon in a large amount of fruit. This

odor has, in fact, come to be the infallible test for brown rot in the lemon curing houses, readily distinguishing the trouble from all other forms of decay. The rapid spread in the box by contact, and the appearance of affected fruit, are also very characteristic, though the latter is soon disguised by Penicillium, and the former feature is even more true with a rot caused by Sclerotinia.

When brown rot first appeared in the packing houses, search was made in the orchard to locate the origin of the trouble, with the result that even upon the tree affected lemons could be found. This was only the case during the wet season, which, in fact, is the only time when the rot is troublesome.

It is not the purpose of the present article to describe this trouble at length, but simply to place on record a description of the fungus and sufficient characterization of its effects to serve to identify this form of lemon decay. Lemons affected on the tree show a brownish, discolored area on the side or end, free from any mould or appearance of fungus, and without any decided softening of the rind, but gradually spreading and soon involving the whole lemon. The fruit keeps its size, shape, and solidity, even when totally affected, before which time it usually drops to the ground. The orchard occurrence is not generally abundant except in wet, warm spring weather or under like conditions. Affected lemons have a peculiar characteristic odor, and are readily identified by one familiar with the disease.

Lemons are usually picked quite green, washed in a machine consisting of a tank of water with revolving brushes, and then stored in boxes for several weeks to cure. At times of abundant prevalence of rot, great loss is experienced in such stored fruit. In lemons apparently sound when put away, affected spots develop on individuals here and there in the boxes. These are soon involved, and also all those which lie in contact with them. These again spread the trouble, and an extremely virulent decay results. Lemons affected in this way have the appearance above described, except that a rather delicate, white mycelium develops on the surface and grows from lemon to lemon, causing the contact infection. The trouble never spreads in the mass of stored fruit except by actual contact of the healthy lemon with an affected spot. When a large

amount of fruit becomes affected the characteristic odor is very pronounced. Penicillium follows rapidly and covers the affected lemons.

With reference particularly to the cause of the trouble, the fungus, which comes out on affected fruit in moist air and spreads from

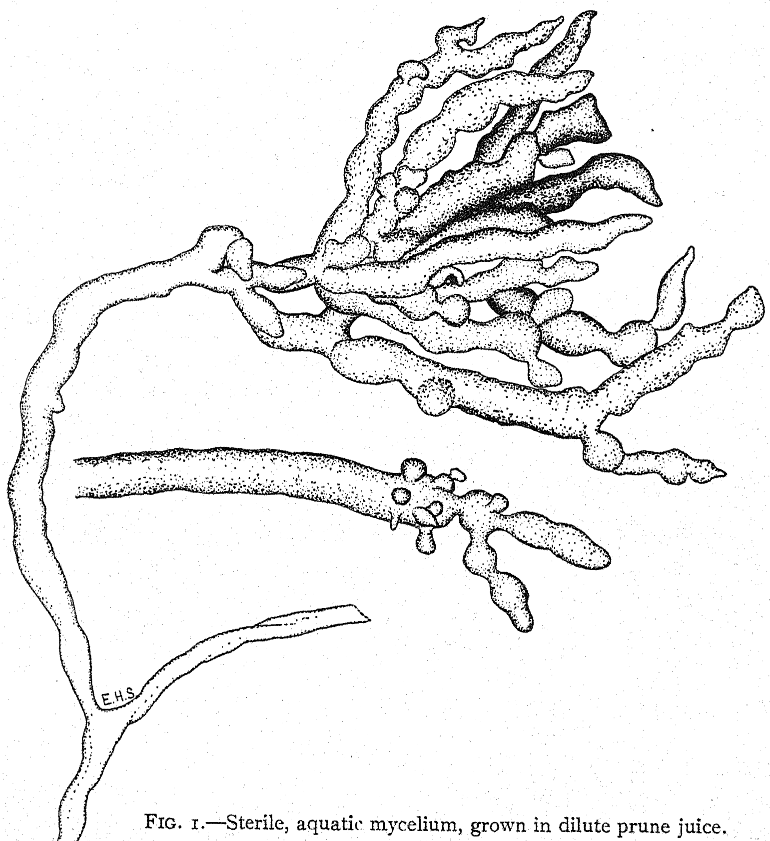

FIG. 1.—Sterile, aquatic mycelium, grown in dilute prune juice.

lemon to lemon, consists of a sterile mycelium, composed of large branching, mostly continuous filaments. If an affected lemon be placed in water for several hours, this mycelium develops more richly upon the surface, forming a slimy, Saprolegnia-like growth. The fungus quickly reaches the fibrous core of the lemon, bits of which soaked in water are soon surrounded with a luxuriant growth

On dry or simply moist media (gelatin, bread, etc.) little or no growth can be obtained. In dilute prune juice the fungus grows with extreme vigor, forming a luxuriant mycelium of very large, branching, continuous filaments (*fig. 1*). Such growths are entirely sterile or nearly so. Occasionally there are produced a few large, ovate, terminal conidia or sporangia, of the phycomycete type, which germinate directly in water or form swarm-spores. Numerous cultures in various liquid media have developed nothing but the mycelium and occasional spores of this kind. This fungus is nearly sterile under such conditions, and entirely so on affected lemons in the air, though with extreme vegetative vigor. Cultures of pieces of affected lemon in pure water, kept for a long time, usually develop nothing but mycelium, though occasionally conidia or sporangia are produced to some extent. Bits of this sterile mycelium placed on sound lemons in a moist chamber produce infection and characteristic rot. Lemons soaked in water, into

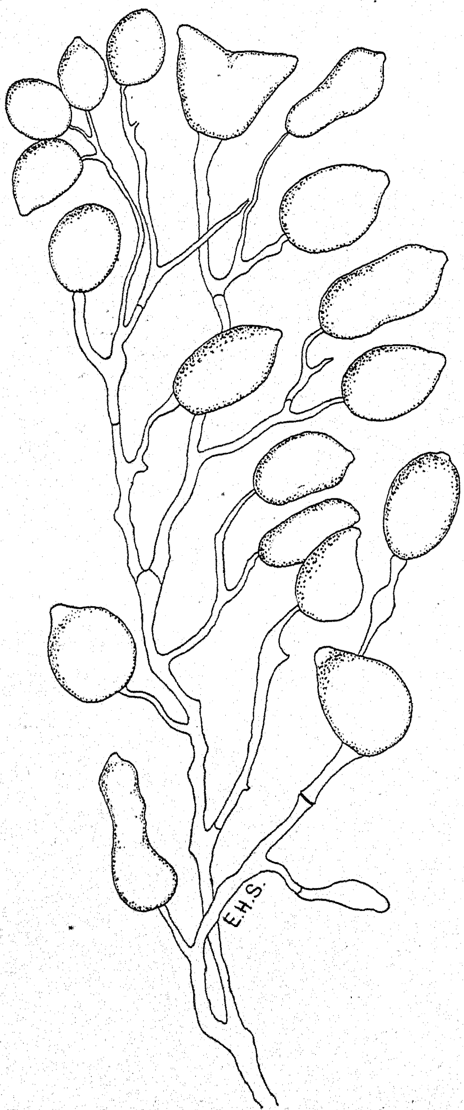

FIG. 2.—Mycelium with sporangia, from moist soil.

which a sterile culture of the fungus has been mixed, also become infected.

Affected lemons placed on moist soil (as in nature by falling from the tree) produce a visible mycelium upon the surface and make such ground highly infectious to sound fruit laid upon the surface. In soil thus inoculated the characteristic spore stage of the fungus has been found. This is also readily produced on wet filter paper

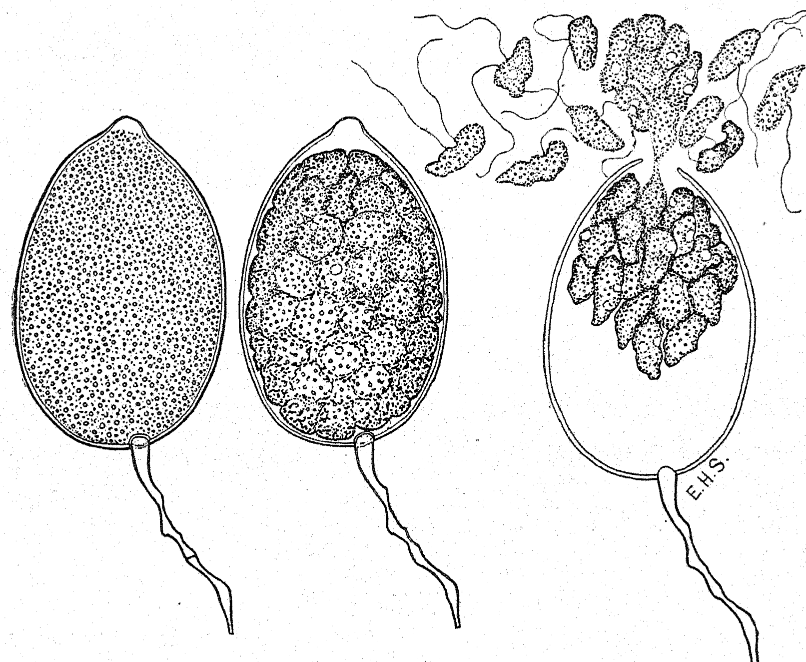

FIG. 3.—Stages in development of swarmspores from sporangia.

in the bottom of a moist chamber containing an affected lemon. Upon an extremely delicate, fine, septate, branching mycelium, very numerous, terminal sporangia are produced (*fig. 2*), much as in Pythium under similar conditions. These sporangia differ, however, from those of the latter genus, in producing swarmspores by direct internal division, behaving in this respect like those of Phytophthora, which they also resemble in appearance (*fig. 3*). The appended description gives further details. These swarm-

spores are extremely infectious to sound, green fruit in all stages of development.

Lemons on the tree become infected during the rainy winter and spring months, almost entirely on the lower part of the trees (which are allowed to branch close to the ground), and in the wettest part of the orchard. The fungus at all times shows a very decided moisture requirement for its development. Infection takes place by swarmspores from the soil, both on the tree and in the washing tank, in the latter case by the orchard dirt, dust, leaves, and other sediment which accumulates in the water.

The writers have given much consideration to the generic relations of this fungus, particularly as to whether it is sufficiently distinct from Pythium and from DE BARY'S Pythiopsis. It is remarkable for the connection which it presents between the Phycomycetes of this nature. While similar to Pythium in habit, except as to its peculiar parasitism on the lemon, this species is definitely excluded from that genus by its internal formation of swarmspores. We have felt considerable hesitancy in separating this form from Pythiopsis, on account of the similarity in swarmspore formation; the latter, however, being founded on a species of such different habit, an entomophthorous form of the Saprolegnieae, and being practically unknown save from the original description, we feel justified in proposing a new genus for our species. It is particularly of interest as being more exactly intermediate between the Saprolegnieae and Peronosporeae than either Pythium or Pythiopsis, and also forming a close transition from Pythium to Phytophthora, having the swarmspore formation and something of the parasitic tendency of the latter. In brief, Pythiacystis has the soil habit of Pythium, the aquatic habit of the same and of the Saprolegnieae (including Pythiopsis) except for its usual sterility under such conditions, the sporangia formation of Pythium, the swarmspore formation of Pythiopsis and Phytophthora, and parasitic activity intermediate between Pythium and Phytophthora.

No indication of sexual reproduction has been observed in the large amount of material and numerous cultures examined.

An Experiment Station bulletin on the nature and control of this fungus will be issued in due time.

Pythiacystis Smith & Smith, n. gen.

Parasitic on living plants, or saprophytic with abundant moisture. Fertile mycelium delicate, septate, with numerous, terminal, sympodially developed sporangia. Aquatic mycelium typically sterile, with occasional conidia or sporangia. Filaments very large and vigorous, continuous, much branched.

Sporangia typically rounded or ovate, dividing internally into biciliate swarmspores which immediately become motile and emerge from a terminal opening.

Conidia similar to sporangia, germinating directly by a germ tube.

Sexual reproduction not observed.

Differs from Pythium in mode of swarmspore formation, and from Pythiopsis in habit. Closely intermediate between Saprolegnieae and Peronosporeae.

Pythiacystis citrophthora Smith & Smith, n. sp.—Parasitic on lemons, and occasionally other Citrus fruits, causing decay of green fruit on the tree and in the storehouse. Mycelium in affected fruit sterile, inhabiting rind and fibrous portions. Internal, except in moist air. Mycelium in water or nutrient liquids very vigorous, usually sterile, or occasionally with conidia or sporangia. Fruiting stage found typically in moist soil, in contact with affected fruit. Sporangia ovate or lemon-shaped, sometimes rounded, considerably elongated, or double, with terminal protuberance; $20 \times 30\mu$ to $60 \times 90\mu$, av. $35 \times 50\ \mu$. Produced in great abundance under favorable conditions. In water dividing quickly by internal division into 5 to 40 (usually about 30) swarmspores, which are immediately set free and discharged through a terminal pore.

Swarmspores 10 to 16 μ in diameter, at first elongated, becoming rounded; with two lateral cilia 30 to 40 μ in length. Actively motile when discharged, soon coming to rest and germinating.

Fungus abundant in winter and spring in southern California lemon orchards and packing houses, causing serious losses.

UNIVERSITY OF CALIFORNIA, BERKELEY.

CURRENT LITERATURE.

BOOK REVIEWS.

American fossil cycads.[1]

SINCE 1898 DR. WIELAND has been investigating the wonderful American display of fossil cycadean forms, usually referred to now as the Bennettitales. The investigation has demanded an unusual amount of patience and hard work in making the necessary collections and sections. The student of living plants has no adequate conception of the labor involved in obtaining valuable results from sectioning fossil material. The result of all this work now appears in a bulky memoir published by the Carnegie Institution. It is a veritable mine of information in reference to Bennettitales, a mine that will be worked by botanists for a long time to come. To present the results here would be to write another book. They are not essentially new, but they are so much more complete and more finely illustrated than ever before that the student of gymnosperms must always consult this volume.

The contents may be outlined by giving the chapter headings as follows: discoveries and collections, preservation and external characters, on the methods of section cutting, trunk structure, foliage, ovulate cones, bisporangiate axes, young fructifications, existing and fossil cycads compared, fern ancestry and angiosperm analogies.

The author is to be congratulated upon the amount of good work that he has accomplished and upon the fine and permanent form in which it has appeared. Morphologists can now lay hold of this material as they never could before, and organize it for general use.—J. M. C.

MINOR NOTICES.

Reproduction.—Under the title "multiplication and sexuality in plants," KÜSTER[2] has published some expanded lectures which were given in January and February of this year and constituted "an advance course for teachers." Vegetative multiplication is first considered in the higher plants, then in the lower. Sexual reproduction is treated historically, and then taken up from the standpoint of its evolution, the lower forms being treated first. The general problems discussed are: sexual affinity, hybridization, polyspermy, parthenogenesis, apogamy, apospory, and distribution of sexes. The book closes with remarks on theories of reproduction and sexuality. It is a convenient, compact, and reliable compendium of the subject.—CHARLES J. CHAMBERLAIN.

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[1] WIELAND, G. R., American fossil cycads. pp. 296. *pls. 50. figs. 138.* Carnegie Institution. 1906.

[2] KÜSTER, ERNST, Vermehrung und Sexualität bei den Pflanzen. 8vo. p. vi+120. *figs. 38.* Leipzig: B. C. Teubner. 1906. *M* 1.25.

Leaflets on Philippine botany.—Under this title A. D. E. ELMER proposes to issue in serial form articles on Philippine plants, both scientific and economic, printed in English, Latin, German, or French. This publication will appear at irregular intervals, at a subscription price of $1\frac{3}{4}$ cents per page, and may be obtained by addressing the editor at Manila. The first issue is a paper of 41 pages entitled *Philippine Rubiaceae*, by the editor, containing 150 species, of which 45 are new, representing 42 genera.—J. M. C.

Das Pflanzenreich.[3]—Part 26 contains the Droseraceae by L. DIELS. Drosophyllum, Dionaea, and Aldrovanda are regarded as monotypic genera; while Drosera is credited with 84 species, 5 of which are new. A very full discussion of structure and range precedes the synopsis.—J. M. C.

Pflanzenfamilien.[4]—Part 224 includes the completion of the Spiridentaceae, the Lepyrodontaceae, and the Pleurophascaceae, and a portion of the Neckeraceae, all by V. F. BROTHERUS. Part 225 continues the Ascolichenes by A. ZAHLBRUCKNER.—J. M. C.

NOTES FOR STUDENTS.

Revelations of the ultramicroscope.—GAIDUKOV has been seeing previously invisible things by means of SEIDENTOPF'S ultramicroscope, and hastens to communicate them in two preliminary papers.[5] After mastering the rather difficult technique and the sources of error, he began by observing the expressed contents of a Vaucheria filament, but later found that it was possible to observe the contents *in situ*. He saw the ultramicroscopic particles of plasma and chlorophyll, the former white and blue, the latter red and green—colors whose significance is unknown as yet for lack of sufficient physical investigation of the instrument. He watched the collision of plasma particles with structureless oil drops and their recoil, and the like collisions of chlorophyll particles and their disappearance in the oil, in which the number of red and green chlorophyll granules steadily increased. This appears to be actually the formation of a colloidal solution of chlorophyll in oil—an oleosol.

In examining a living filament he found that the protoplasm occupied a much greater space than appears with ordinary illumination, only a very small part of the filament being optically empty. In the chloroplasts of Mesocarpus, roundish or stellate flecks of chlorophyll particles are distributed through the stroma, whose structure is like that of the protoplasm; there is no indication of the solution of chlorophyll in oil droplets lying in the stroma—a widely accepted notion.

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3 ENGLER, A., Das Pflanzenreich. 26 Heft. Droseraceae von L. DIELS. pp. 136. *figs. 40 (286), map 1*. Leipzig: Wilhelm Engelmann. 1906. *M* 6.80.

4 ENGLER, A. und PRANTL, K., Die natürlichen Pflanzenfamilien. Lieferungen 224 and 225. Leipzig: Wilhelm Engelmann. 1906.

5 GAIDUKOV, N., Untersuchungen mit Hilfe des Ultramikroskopes nach Seidentopf. Ber. Deutsch. Bot. Gesells. **24**: 107–112, 155–157. 1906.

The nucleus of Tradescantia appears to have a structure like protoplasm, but much more compact.

Bending movements of Oscillaria are accompanied by wave-like movements of particles in the cells; and the longitudinal movements by a streaming of particles on the surface in a direction opposite to that of the motion of the filament. These particles pass off into the water when they reach the end of the filament.

Ultramicroscopic organisms in figure-of-8 forms, and colonies in form like certain flagellates, similar to the organisms already described by RAEHLMANN, were found in every preparation.

Protoplasmic movements have been seen in all organisms investigated, and the ordinary rotation and streaming is by no means the simple flow it seems to be, but is probably initiated by a complex motion of the ultramicroscopic particles (ultramicrons) of the protoplasm, whose structure seems identical with that of colloidal solutions as determined by ZSIGMONDY with the instrument. The first movement, indeed, may be what has long been known as the Brownian movement, once so carefully distinguished from the "vital" ones as "purely physical."

In plasmolysis GAIDUKOV has seen the protoplasmic particles move from the periphery toward the center of the cell, changing shape at the same time from round to vermicular, while in the chloroplast simultaneously the vermicular chlorophyll particles creep out upon the surface. In Flagellatae there is a vigorous movement of particles in the region of the cilia and below the mouth opening, before the gross movements begin.

Whereas in chlorophyllose cells the cell wall is optically empty (*leer*), enabling one to see the cell contents clearly, the wall of bacteria and fungi has so complex a structure that nothing can be seen through it. Yet the purple bacteria which also work photosynthesis have a wall optically empty. These facts are believed to be related to the necessity for transparence to light in photosynthetic cells.—C. R. B.

Araucarieae.—A. C. SEWARD and SIBILLE O. FORD have published the results of a study of the Araucarieae.[6] The two living genera representing the group, Agathis and Araucaria, have long stood somewhat stiffly apart from other Coniferales, not only on account of the known facts in reference to them, but chiefly, perhaps, on account of lack of knowledge. The authors have marshalled our knowledge of extinct and living forms in this memoir; and however opinions may differ as to their conclusions, there can be only one opinion as to the value of the work. The subject is presented under the following captions: distribution, generic diagnosis, seedlings, stem anatomy, roots, leaves, leaf-traces, reproductive shoots, fossil Araucarieae, and phylogenetic considerations and conclusion. The details are too numerous to be included in a review, but the conclusions are too important to be passed over lightly.

[6] SEWARD, A. C. and FORD, SIBILLE, O., The Araucarieae, recent and extinct. Phil. Trans. Roy. Soc. London. B. **198**:305–411. *pls. 23–24. figs. 28.* 1906.

In general, the memoir is a contention that the recent brilliant work which has knit together cycads and Filicales has developed the too sweeping conclusion that all gymnosperms have the same phylogenetic connection; that the old view suggesting a connection between conifers and lycopods deserves more attention than it has been receiving; and that at least the Araucarieae strongly suggest a lycopod origin. It is urged upon paleobotanical evidence that the Araucarieae are the most primitive of Coniferales, certainly more primitive than the Abietineae; and that this testimony from history is supported by numerous evidences of relatively primitive structures still exhibited by Agathis and Araucaria. The difficult question of the Cordaitales, which seem to combine characters of Cycadales and Coniferales and so necessitate a common phylogeny, is disposed of by minimizing their resemblances to the latter, at least to the Araucarieae. It must be remarked that the authors repeatedly emphasize the fact that they are dealing only with the Araucarieae, and that it does not affect their main contention whether the other Coniferales are related to a filicinean ancestry through the Cordaitales or not. In developing the differences between the Araucarieae and other Coniferales, they have been so impressed by their importance that they have suggested a group *Araucariales*, coordinate with Coniferales, Cycadales, etc. For this group, at least, they claim a lycopod ancestry, through some such form as Lepidocarpon, emphasizing the seed-like sporangia recently described by SCOTT in that genus.

The authors are to be congratulated upon a very fair statement of their case, a statement which dodges none of the difficulties, and which really does not claim very much more than that an almost abandoned hypothesis must not be neglected.

A very interesting appendix to this memoir may be obtained by reading the report[7] of two recent meetings of the Linnean Society, at which various views as to the origin of gymnosperms were presented and combated by English students of the group.—J. M. C.

Items of taxonomic interest.—N. L. BRITTON (Bull. N. Y. Bot. Gard. **4**:115–127, 137–143. 1906) describes new species of Bahama plants under Coccolobis, Caesalpinia, Canavalia, Hibiscus, Heliotropium (2), Lantana (2), Cestrum, Stemmodontia, Anastraphia, Marsilea, Dondia, Cassia, Maytenus, Myroxylon, Opuntia, Limnanthemum, Metastelma, Aster.—W. H. BLANCHARD (Torreya **6**:147–149. 1906) has described 2 new species of Rubus (dewberries) from New England.—H. D. HOUSE (*idem* 150) has described a new Convolvulus from Georgia.—H. A. GLEASON (Bull. Torr. Bot. Club **33**:387–396. 1906) has revised the pedunculate species of Trillium, defining 19 species, 3 of which are new.—H. D. HOUSE (Rhodora **8**:117–122. 1906) has described the violets and violet hybrids of the District of Columbia and vicinity, recognizing 26 species, and describing 8 new hybrids.—M. L. FERNALD (*idem* 126–130) has described new species of Cyperus (2) and Eleocharis from Eastern North America.

7 New Phytol. **5**:68–76, 141–148. 1906.

—E. B. COPELAND (Philippine Jour. Sci. 1:143–166. *pls. 28.* 1906) has described 47 new species and 2 new genera (*Acrosorus* and *Thayeria*) of Philippine ferns. —SPENCER LE M. MOORE (Jour. Botany **44**:217–224. 1906) has described 2 new genera of Acanthaceae from Madagascar, *Melittacanthus* and *Amphiestes*.—BUNZO HAYATA (Jour. Linn. Soc. Bot. **37**:330. *pl. 16.* 1906) has described a new genus (*Taiwania*) of conifers from the Island of Formosa, belonging to the Taxodieae and nearest to Cunninghamia.—EDITH M. FARR (Ottawa Nat. **20**:105–111. 1906) has described new species from the Canadian Rockies and Selkirks under Pachystima (4), Arnica, Hieracium, Dryas, and Ranunculus.— O. STAPF (Kew Bulletin 1906 : 204) has published a new genus (*Diandrolyra*) of grasses whose native country is unknown.— O. E. JENNINGS (Annals Carnegie Mus. 3 : 480–485. 1906) has published new species under Kneiffia and Ibidium (Spiranthes) from Pennsylvania.—V. F. BROTHERUS (Hedwigia **45** : 271. 1906) has described a new genus (*Uleobryum*) of Pottiaceae from Peru.—F. LAMSON-SCRIBNER (Rhodora **8** : 137–146. 1906) has included in a newly named genus (*Sphenopholis*) the grasses that have been referred for many years to *Eatonia* Raf., recognizing 7 species.—W. H. BLANCHARD (*idem* 146–157) has described 5 new blackberries (Rubus) from Maine.—R. SCHLECHTER (Engler's Bot. Jahrb. **38** : 137–143. 1906) has described two new African genera (*Afrothismia* and *Oxygyne*) of Burmanniaceae.—J. C. ARTHUR and F. D. KERN (Bull. Torr. Bot. Club **33** : 403–438. 1906), in a revision of the N. Am. species of Peridermium, recognize 30 species, 10 of which are described as new.—K. K. MACKENZIE (*idem* 439–443) has described 4 new species of Carex.—LEROY ABRAMS (*idem* 445–446) has described 2 new southwestern species of Pentstemon.—J. M. C.

Japanese Experiment Station Bulletin.—A new departure in experiment station publications had been inaugurated by Professor HOZAI of the Imperial Central Agricultural Experiment Station of Tokio. In order to make the results of work carried on in the experiment stations of Japan accessible to investigators of other countries, a periodical Bulletin will be issued in which all work that may be of general interest will be published. The experimental system of Japan comprises 47 stations, whose work will in large part become available to the world through the publication of this Bulletin, printed partly in English and partly in German. The first number[8] contains 11 articles, some of which are briefly noted here to show the scope of the publication. S. MACHIDA reports on the influence of dilute solutions (0.3%) of Ca and Mg salts on the putrefactive action of bacteria. The rate of putrefaction was determined by the quantity of NH_3 formed in urine and in pepton solutions to which the salts had been added. It was found that the Ca-salts retard putrefaction, while Mg-salts favor the process.

Several articles of agronomic interest are given by G. DAIKUHARA on the correction of an unfavorable ratio of lime to magnesia, also on the lime factor

[8] The Bulletin of the Imperial Central Agricultural Experiment Station, Japan. Vol. I. No. 1. pp. 94. *pls. 13.* Nishigahara, Tokio. December 1905.

for the tobacco plant, and on the application of magnesia in the form of magnesium sulfate for the rice plant. UYEDA gives an extended account of a new phytopathological bacterium (*Bacillus Nicotianae*) which produces a serious disease known as stem-rot and black-leg of tobacco. HORI gives an account of a smut on the cultivated bamboo. The fungus attacks the young internodes of growing branches, and as it may infect these at any time during the growing season, whole forests of bamboo often become infected. As the bamboo furnishes material for building as well as for household utensils and fences, the damage thus caused is considerable. The fungus is referred to *Ustilago Shiraiana* P. Henn.—H. HASSELBRING.

Respiratory enzymes.—PALLADIN announces his adherence to the theory of BACH and CHODAT, that normal respiration depends upon the presence of 1) oxidizable substance and 2) two enzymes, whose mixture was formerly designated oxidase, *a*) oxygenase, which has, attached to various radicals, the characteristic peroxid or hydroperoxid group O·O or O·OH and serves to transfer O_2, and *b*) peroxydase, which is a catalyser and renders active the oxygenase. When oxidative processes do not occur it is because one or two of the three are wanting. The less stable oxygenases, and those which with water quickly become hydroperoxids, are used up promptly, giving rise to some of the respiratory CO_2; so that often tests do not show any "oxidase" present in plant parts; but the peroxidases, which are very stable, can always be found.

From his researches PALLADIN concludes[9] that the prevalence of one or the other enzyme is connected with the stage of development of the plant. For anaerobic respiration prevails in embryonal organs and in lower plants, which alone are capable of anaerobic life. In the embryonal stage oxygenase is at a minimum, increasing with the passage into active life, and diminishing in organs which have ceased to grow.

Miss KRASNOSSELSKY,[10] working under PALLADIN'S direction, finds in frozen onions and their sap no oxygenase, but peroxydases whose quantity increases with respiratory activity, if H_2O_2 be supplied, and continues to do so even when respiration falls. Katalase, however, is present in the sap after the freezing.

These researches are more and more justifying the opinion that the origin of "respiratory" CO_2 is very complex, and that more than one catalyser is taking part in the dissociation.—C. R. B.

Ancient history of ferns.—ARBER[11] has brought together the recent development of knowledge in reference to the history of ferns in a short paper that brings

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9 PALLADIN, W., Bildung der verschiedenen Atmungsenzyme in Abhängigkeit von dem Entwicklungstadium des Pflanzen. Ber. Deutsch. Bot. Gesells. **24**:97–107. 1906.

10 KRASNOSSELSKY, T., Bildung der Atmungsenzyme in verletzten Zwiebeln von *Allium Cepa*. Ber. Deutsch. Bot. Gesells. **24**:134–141. 1906.

11 ARBER, E. A. NEWELL, On the past history of ferns. Annals of Botany **20**: 215–232. 1906.

the important facts well in view, however opinions may differ as to some of the conclusions. It is shown that the fern-like Cycadofilices, later called Pteridosperms, were a dominant group of the Carboniferous; but that the evidence for the existence of ferns in the modern sense is at present very uncertain. For any Carboniferous fern-like plants that may prove to be true ferns the author suggests the name *Primofilices*, since to distinguish among them definite eusporangiate and leptosporangiate habits is impossible. In fact, all the so-called "fructifications" of Paleozoic "marattiaceous ferns" may prove to be the microsporangiate structures of Pteridosperms. Until this is determined, the existence of eusporangiate ferns in the Paleozoic as a dominant group must remain uncertain. This also means that the old question as to whether the eusporangiate or the leptosporangiate type of ferns is the more primitive has lost its apparently sure answer from history. In fact, while the author gets sure evidence of leptosporangiate ferns in the Permian, he does not find similar satisfactory evidence of eusporangiate ferns until the Tertiary; although in both cases he recognizes the possible Paleozoic occurrence. As to the water ferns, the evidence of their existence does not become clear until the Tertiary. The claims for them in the Paleozoic are so much in conflict with all morphological testimony that they have never seemed to be very serious. The general conclusion in reference to the ferns seems to be that while Pteridosperms are a dominant group in the Paleozoic; and the Cycadophyta are one of the dominating groups of the Mesozoic; there is no evidence at present of the dominance of any fern group except that of the leptosporangiates in the Mesozoic and continuing into the present flora.—J. M. C.

Spores of Riccia glauca.—BEER[12] has investigated the development of the spores of *Riccia glauca*, contrasting his results with those of GARBER[13] on *R. natans*, and of LEWIS[14] on *R. crystallina*. The spore mother cells are at first separated by extremely delicate membranes in which no cellulose could be demonstrated, and upon them secondary and tertiary thickening layers are deposited which give pectose-cellulose reactions. The secondary layer becomes more or less mucilaginous, sometimes separating completely from the primary wall, at other times remaining partly adherent and becoming drawn out into strands bridging the space between the primary wall and the tertiary layer. No nutritive material was found between the isolated mother cells, and no non-nucleated reticular resting nucleus was found. The large deep-staining nucleolus consists of a number of deeply chromatic granules embedded in a faintly staining matrix. A long and well-marked spirem thread occurs in the prophase of the division of the mother cell. The reduced number of chromosomes is 7 or 8. In telo-

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[12] BEER, RUDOLF, On the development of the spores of *Riccia glauca*. Annals of Botany **20**:275–291. *pls. 21–22*. 1906.

[13] BOT. GAZETTE **37**:161–177. 1904.

[14] BOT. GAZETTE **41**:109–138. 1906.

phase a number of chromatic bodies (presumably derivatives of the chromosomes) are distributed on the linin fibers, and subsequently aggregate to form the lobular nucleolus of the resting nucleus. The first spore wall is cuticularized from a very early period, and within it, at the equatorial rim, a plug of mucilage is deposited. The second spore wall is formed within the first wall, and is also cuticularized; at first it appears homogeneous, but subseqently is composed of three regions. The endospore (pectose and cellulose) is formed late, and is often separated from the second wall by a thin band of dark material.—J. M. C.

Postelsia.[15]—Four years ago the first volume under this title appeared,[16] containing seven papers by members of the Minnesota Seaside Station on the coast of Vancouver. The present volume is printed in the same handsome style, and also contains seven papers as follows: Observations on plant distribution in Renfrew district of Vancouver Island (pp. 1–132. *pls. 1–11*), by C. O. ROSENDAHL; The Conifers of Vancouver Island (pp. 133–212. *pls. 12–15*), by F. K. BUTTERS; Hepaticae of Vancouver Island (pp. 213–235), by ALEXANDER W. EVANS; Some western Helvellineae (pp. 236–244), by D. S. HONE; *Renfrewia parvula*, a new kelp from Vancouver Island (pp. 245–274. *pls. 16–19*), by ROBERT F. GRIGGS; A study of the tide-pools on the west coast of Vancouver Island (pp. 275–304, *pls. 20–25*), by ISABEL HENKEL; Some geological features of the Minnesota Seaside Station (pp. 305–347. *pls. 26–33*), by C. W. HALL.

The paper on plant distribution reaches the conclusion that the pteridophytes are poor in species for so moist a region, that the gymnosperms constitute the great mass of the vegetation, and that the monocotyledons are more important than the dicotyledons. The paper on conifers contains very interesting observations, treats Picea, Tsuga, and Pseudotsuga as sections under Abies, and organizes a key to the northwestern genera on the basis of foliage. *Renfrewia* is a new genus of kelps nearest to Laminaria and Cymathere.—J. M. C.

Synapsis and reduction.—From a study of the pollen mother cells of *Acer platanoides*, *Salomonia biflora*, *Ginkgo biloba*, and *Botrychium obliquum* CARDIFF draws the following conclusions.[17] Synapsis is a constant morphological character of the mother cell, and the unilateral position of the synaptic knot is probably due to gravity. Previous to synapsis the chromatin is in two or more threads which arrange themselves in pairs, longitudinally, and finally fuse during synapsis, but there is not a complete mingling of chromatin substance in the chromatic thread. The thread splits longitudinally in the first mitosis, probably along the line of previous fusion. The chromosomes are of different sizes and do not behave alike at the first mitosis.

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15 The year book of the Minnesota Seaside Station. 1906. pp. 364. *pls. 33*. Obtained from Josephine E. Tilden, Univ. Minn., Minneapolis. $2.25.

16 BOT. GAZETTE 34:468. 1902.

17 CARDIFF, I. D., A study of reduction and synapsis. Bull. Torr. Bot. Club 33:271–306. *pls. 12–15*. 1906.

It is probable that at fertilization there is a nuclear but not a chromatin fusion, and that the paternal and maternal chromatin retain their identity throughout the sporophytic phase, finally fusing, in so far as they fuse at all, during synapsis. If this be true, the two important phenomena of fertilization—stimulus to growth and intermingling of ancestral characters—are widely separated, the stimulus to growth occurring when the nuclei fuse, and the mingling of characters being delayed until synapsis.—CHARLES J. CHAMBERLAIN.

Nutrition of the gymnosperm egg.—Miss STOPES and FUJII[18] have been investigating the nutritive relations of the surrounding tissues to the egg in gymnosperms. As is well known, about the "central cell," and later about the egg, there is organized usually a very distinct jacket of nutritive cells, whose inner walls are conspicuously thickened and pitted. The authors find that the delicate walls of the endosperm cells are pitted in the same way; and that the large pits of the jacket cell-walls are closed by a membrane perforated only by plasmodesmen. This latter fact is the most interesting one of the paper, for it precludes the old notion of nuclear migration or of any transfer of solid material from the jacket cells to the egg. The jacket cells are regarded as glandular, secreting substances for the digestion of the starch and proteid granules stored in the endosperm. The statement is made in the summary that the jacket cells "are considered the phylogenetic homologues of the angiospermic antipodals," a statement evidently based upon their similar function.—J. M. C.

Ecological survey of Northern Michigan.—Under the direction of C. C. ADAMS there has been published[19] the report of an ecological survey conducted by the University Museum of the University of Michigan in 1904. The regions selected were Porcupine Mountains in Ontonagon County, on the south shore of Lake Superior, and Isle Royale, an island near the Canadian shore. Especially significant is the report by A. G. RUTHVEN on the relation of the plants and animals of these regions to their environment. Lines of survey were run across the region examined, in such a way as to include examples of all the representative habitats. These habitats were then examined in as much detail as time permitted, and special attention was given to the relations of the "biota" to its environment. In this study attention was directed particularly to the forces and conditions composing the environment, in order that the dominant forces might be clearly recognized. The results are too numerous and detailed for mention, but the work is unique and extremely suggestive.—J. M. C.

Ecology of algae.—FRITSCH[20] has made a statement of some of the problems

[18] STOPES, M. C. and FUJII, K., The nutritive relations of the surrounding tissues to the archegonia in gymnosperms. Beih. Bot. Centralb. **20**:1–24. *pl. 1.* 1906.

[19] An ecological survey in Northern Michigan. Prepared under the direction of CHAS. C. ADAMS. Publ. in Rep. State Geol. Survey for 1905. pp. 133. *figs. 21.* 1906.

[20] FRITSCH, F. E., Problems in aquatic biology, with special reference to the study of algal periodicity. New Phytol. **5**:149–169. 1906.

connected with the study of algal ecology, and has suggested some means towards their solution. The first problem considered is the determination of what shall constitute a formation, and the contrast with terrestrial formations is made. Suggestions are made as to the significant unit and examples are given. Chief attention, however, is given to algal periodicity, the seasonal variations of algae being much greater than those of terrestrial plants. "In most cases in an aquatic flora a number of dominant forms succeed one another in the course of a year, and after their period of prevalence is past they disappear either suddenly or gradually." Periodicity of algae is either seasonal or irregular, and the factors concerned in both of these cases are discussed. In illustration of his statements, the author discusses the algal flora of a particular pond. The paper is a distinct stimulus to the study of pond life in an effective way.—J. M. C.

Decay of timber.—Following the lines of investigation laid down by HARTIG in his *Zersetzungserscheinungen des Holzes*, BULLER[21] has contributed a further study on the subject of the decay of timber caused by the higher fungi. The form studied is the common *Polyporus squamosus*, which is found on many species of broad-leaved trees. Like other forms of this class, the fungus gains entrance to the tree through wound surfaces. The mycelium progresses more rapidly in a longitudinal direction in the wood, so that the decayed region extends many feet up and down the trunk and principal branches, while advancing only a few inches in a radial direction. The hyphae penetrate into all the wood cells. The decaying wood is lighter in color than the sound wood. In the final stages of the decay the wood cracks into cuboidal blocks, with the intervening crevices filled with strands of the white mycelium of the fungus. The decayed wood is somewhat richer in carbon and poorer in oxygen and nitrogen than sound wood.—H. HASSELBRING.

Apogamy in Dasylirion.—WENT and BLAAUW[22] have described apogamy in *Dasylirion acrotrichum*, in the case of plants in cultivation in the Utrecht Botanical Garden. This Mexican species is dioecious, and no staminate plants exist in the garden, thus precluding the possibility of fertilization. A certain number of fruits matured sufficiently to attract attention, and an examination of the ovules discovered embryo sacs containing endosperm tissue in various stages of development, in some cases completely filling the sac. Dasylirion is thus added to the very few illustrations of endosperm-formation without fertilization. In these endosperm-containing sacs no embryos were found, but in some others a group of cells was discovered in the usual position of the egg-apparatus, which the authors seem justified, judging from the figures, in regarding as a young embryo. The position would suggest a case of parthenogenesis, but there is room for doubt, and the authors prefer to speak of it as a case of apogamy.—J. M. C.

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[21] BULLER, A. H. REGINALD, The biology of *Polyporus squamosus* Huds., a timber-destroying fungus. Jour. Econ. Biol. 1:101–138. *pls. 5–9.* 1906.

[22] WENT, F. E. F. C. and BLAAUW, A. H., A case of apogamy with *Dasylirion acrotrichum* Zucc. Recueil Trav. Bot. Néerland. no. 3. pp. 12. *pls. 5.* 1905.

Photosynthesis by carotin.—KOHL[23] shows by new experiments that the secondary maximum in the curve of photosynthesis, as drawn by ENGELMANN, is due to carotin. He eliminates the possible error in this determination (made by an improvement of the bacterial method), showing that the bacteria are in nowise affected by the F-rays alone. But when algae are illuminated only by rays absorbed by carotin, the movement of the bacteria begins, indicating evolution of O_2. He also shows that though O_2 is necessary to the formation of chlorophyll, etiolated leaves may become green in an O-free chamber, provided CO_2 is not in excess, since they can use the O_2 set free in photosynthesis. Of etiolin KOHL can find no trace, and he holds it certain that neither carotin nor xanthophyll (the latter probably a transformation product of the former) can be antecedents of chlorophyll. Whatever gives rise to it is probably colorless.—C. R. B.

Poisonous Colorado plants.—GLOVER[24] reports the results of studies of larkspur and other poisonous plants in Colorado. Of the eighteen species of Delphinium found in Colorado the most serious pests in this connection are *D. elongatum* and *D. Nelsonii.* He finds that the larkspur gradually becomes less and less toxic as it approaches the flowering period and finally becomes entirely harmless. The toxic principle has not yet been determined for these species, but is probably delphinine and some other related alkaloids. Other poisonous plants mentioned are species of Zygadenus, Cicuta, Lupinus, and Hymenoxys. The last plant is not strictly poisonous, but forms after being eaten a rubbery mass that may prove injurious. The bulletin contains a useful bibliography of the literature of plants poisonous to cattle on the range.—E. MEAD WILCOX.

Ecology in the Philippines.—It is a matter of no small interest to receive the first extended ecological study of a region of the Philippines. WHITFORD'S[25] account of the vegetation of the Lamao forest reserve introduces us to a tropical region, where the details of plant ecology are new and fascinating, and where the problems must be peculiarly complex. The Lamao forest reserve is in the province of Bataan (Luzon), on the east slope of a group of volcanic peaks known as Mount Mariveles. After the introductory statements as to geology and physiography, climate, and soil, the vegetation is discussed at length under six formations: Strand, Bambusa-Parkia, Anisoptera-Strombosia, Dipterocarpus-Shorea, Shorea-Plectronia, and Eugenia-Vaccinium. The half-tone plates are numerous and present most interesting views of tropical vegetation.—J. M. C.

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[23] KOHL, F. G., Die assimilatorische Funktion des Karotins. Ber. Deutsch. Bot. Gesells. **24**:222–229. 1906.

[24] GLOVER, G. H., Larkspur and other poisonous plants. Bull. Col. Exp. Sta. **113**:1–24. *pls. 1–8.* 1906.

[25] WHITFORD, H. N., The vegetation of the Lamao forest reserve. Philippine Jour. Sci. **1**:373–431, 637–679. *map* and *pls. 1–45.* 1906.

Azotobacter.—STOKLASA and his assistants have been cultivating *Azotobacter chroococcum* and *Radiobacter* sp. to determine the fixation of nitrogen and the fermentative respiratory activity.[26] They do not confirm BEIJERINCK'S assertion that Radiobacter fixes free N, nor that Azotobacter in company therewith fixes more N than in pure culture. They conceive the fermentation of the mannits and of glucose by Azotobacter to be wrought by glycolytic enzymes which split them into lactic, acetic, and formic acids and alcohol. By the decomposition of these, CO_2 and H_2 are produced, the former at greater rate than in any organisms previously known. Thus 1^{gm} of Azotobacter, dry weight, produces on an average 1.3^{gm} CO_2 in 24 hours. The H_2 is believed to have an important rôle in the fixation of N.—C. R. B.

Subalpine scrub in New Zealand.—COCKAYNE[27] has named the distinct zone of plants on many New Zealand mountains between the limit of the forest and the subalpine meadow the "subalpine scrub." On Mount Fyffe this formation differs from the typical one in the paucity of species and in the great domination of *Cassinia albida*, a species peculiar to that locality, in places being almost a pure formation. *Ranunculus lobulatus*, another local species, is the principal plant beneath the scrub. Some of the shrubs are strongly xerophytic; and the author thinks that the amount of xerophylly observed in many New Zealand plants is by no means a measure of their adaptation to present environment, but rather a survival from previous more xerophytic conditions.—J. M. C.

Monoecism of Funaria hygrometrica.—BOODLE[28] has undertaken to settle the contradictory statements in reference to the distribution of the male and female organs of this species. It seems that bryological works describe it as monoecious; and that certain general textbooks speak of it as dioecious. It turns out that the bryologists are right, as might have been expected. "The male axis bears a terminal male flower, and produces a lateral branch (innovation) which forms a terminal female flower. The female branch may be inserted at different levels, sometimes high up, sometimes basally; it usually has a tuberous base bearing a tuft of rhizoids, and if torn away appears like an independent plant."—J. M. C.

Color of algae.—GAIDUKOV exposed the blue-green plates of Phormidium and the red Porphyra to the spectrum of a strong electric light.[29] In ten hours under all the green to violet rays the color had become yellow to brown-yellow,

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[26] STOKLASA, J., et al., Ueber die chemischen Vorgänge bei der Assimilation des elementaren Stickstoffes durch Azotobacter und Radiobacter. Ber. Deutsch. Bot. Gesells. **24**:22–32. 1906.

[27] COCKAYNE, L., Notes on the subalpine scrub of Mount Fyffe. Trans. N. Z. Inst. **38**: 361–374. 1906.

[28] BOODLE, L. A., The monoecism of *Funaria hygrometrica* Sibth. Annals of Botany **20**:293–299. 1906.

[29] GAIDUKOV, N., Die komplementäre chromatische Adaptation bei Porphyra und Phormidium. Ber. Deutsch. Bot. Gesells. **24**:1–5. 1906.

remaining blue-green under the red to yellow rays. Porphyra remained red in the green-violet, but became green in the red-yellow. The pigments thus become of the complementary color to the incident light, and change in a time inversely proportional to the intensity of the light. The same change, but much slower, had been observed by the author in nature, and he considers this complementary chromatic adaptation the chief factor in determining the color of algae.—C. R. B.

Pollen tubes of Cucurbitaceae.—KIRKWOOD[30] has been studying the behavior of the pollen tubes of *Melothria pendula*, *Micrampelis lobata*, and *Cyclanthera explodens*. He has noted that the time elapsing between pollination and the arrival of the tube at the embryo sac in these species is 26, 19, and 41 hours respectively. The tubes pass chiefly over the surface of the conducting tissue, lining the stylar canal and covering the "placental lobes," and this is rich in starch. The suggestion is made that the tube is directed by "nutritive substances secreted by the conducting tissue," and that it "comes under the influence of a stronger stimulant emanating from the ovule," and "the source of this stimulus may be the endosperm nucleus."—J. M. C.

Morphology of Phyllocladus.—Miss ROBERTSON[31] has obtained some glimpses of Podocarpus from cultivated species and five collections of *P. alpinus* secured in New Zealand by Dr. COCKAYNE during 1902, 1903, and 1904. It is disappointing to learn that no critical stages were fixed, and that we are still on the outside of this interesting genus. However, it is of no small interest to learn that centripetal xylem occurs in the cladodes and is restricted to them. This feature is quite characteristic of the Taxus-forms; while the winged pollen grains belong to the Podocarpus-forms. These and other characters emphasize the intermediate position of Phyllocladus between the two prominent tribes of Taxaceae.—J. M. C.

Parichnos in recent plants.—HILL[32] has reached the conclusion that parichnos, a name given by BERTRAND to the strand of thin-walled parenchymatous tissue accompanying the leaf trace in a species of Lepidodendron, is represented among living species of Lycopodium and Isoetes by certain mucilage canals. The tissue to which the name was given is simply an early developmental stage of the canal. In recent plants parichnos is restricted chiefly to the sporophylls, as, for example, in *Isoetes Hystrix*, where two canals run longitudinally on each side of the sporangium, but do not extend into the cortex of the stem, as is the case in fossil forms.—J. M. C.

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[30] KIRKWOOD, JOSEPH EDWARD, The pollen tube in some of the Cucurbitaceae. Bull. Torr. Bot. Club 33:327–342. *pls. 16–17.* 1906.

[31] ROBERTSON, AGNES, Some points in the morphology of *Phyllocladus alpinus* Hook. Annals of Botany 20:259–265. *pls. 17–18.* 1906.

[32] HILL, T. G., On the presence of a parichnos in recent plants. Annals of Botany 20:267–273. *pls. 19–20.* 1906.

Spore formation in Botrychium.—The development of the spores and the behavior of the tapetum in *Botrychium virginianum* are described by STEVENS.[33] CARDIFF had already published an essentially identical account of the tapetum.[34] STEVENS's term *tapetal plasmodium* seems to be a suggestive and convenient name for the peculiar tapetal mass as it appears in Botrychium and many other pteridophytes. The behavior of the kinoplasm and trophoplasm during the formation of spores from the mother cell indicates that these two plasms are interchangeable, each being able to become transformed into the other.—CHARLES J. CHAMBERLAIN.

Dichotomous leaves in Cycas.—SEWARD[35] has called attention to the dichotomous leaves of *C. Micholitzii*, a subterranean-stemmed species from Annam. Most of the pinnae are repeatedly dichotomous, but the terminal pinnae are simple and similar to those of other species of the genus. It seems that dichotomous pinnae in the cycads were first noted by MOORE in the Australian *Macrozamia heteromera*. The author suggests the possibility that the usual simple pinnate type of the cycadean leaf "may be the result of reduction from an older type characterized by the more primitive dichotomous habit."—J. M. C.

Diatomin.—KOHL was incited by the papers of MOLISCH[36] and TSWETT[37] to reinvestigate the coloring matter of diatoms,[38] having denied in his work on carotin the existence of a special pigment, "diatomin." He now finds that his conclusion was correct as regards any special "diatomin;" but the pigment is not carotin and xanthophyll alone, as he declared, chlorophyll, with the same absorption spectrum as in higher plants, being also present. The leucocyan of MOLISCH he does not find. The yellowish or brownish hue of the diatoms is due to the prevalence of carotin as compared with the higher plants.—C. R. B.

Germination in Ophioglossum.—The difficulty and the desirability of securing the germination of the spores of the pteriodophytes with tuberous gametophytes are well known. CAMPBELL announces (Annals Bot. **20**: 321) in a brief note that he has secured germination in certain Javanese species of Ophioglossum. In every case the characteristic endophytic fungus was present beyond the three-celled stage. In one case a gametophyte of thirteen cells was found; but no stage between this and mature gametophytes were secured.—J. M. C.

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33 STEVENS, W. C., Spore formation in *Botrychium virginianum*. Annals of Bot. **19**:465–474. *pls. 18–20.* 1906.

34 CARDIFF, I. D., The development of the sporangium of Botrychium. BOT. GAZETTE **39**:340–347. *pl. 9.* 1905.

35 SEWARD, A. C., Notes on Cycads. Proc. Cambridge Phil. Soc. **13**:293–302. 1906.

36 MOLISCH, H., Bot. Zeit. **63**^{1}:131–162. 1905.

37 TSWETT, M., *ibid.* 273–278.

38 KOHL, F. G., Die Farbstoffe der Diatomeen-Chromatophoren. Ber. Deutsch. Bot. Gesells. **24**:124–134. 1906.

Cytology of Entomophthoraceae.—One species of Empusa and four of Entomophthora have been studied by Riddle.[39] In Entomophthora the division is more or less typically mitotic. During prophase the chromosomes are formed by a direct aggregation of the chromatin granules without the previous formation of a spirem. In the formation of zygospores the fusing bodies are coenogametes. The writer suggests that the azygospore of Empusa is of the nature of a chlamydospore. Cytological conditions indicate that Entomophthora is a more highly developed genus than Empusa.—CHARLES J. CHAMBERLAIN.

Lime and sphagna.—As a result of cultures PAUL, in a preliminary paper,[40] confirms the older and still prevalent idea that the sphagna are very sensitive to the presence of $CaCO_3$ in the water in which they grow, and controverts the pronouncements of WEBER and of GRAEBNER. *Sphagnum rubellum* is most sensitive, bearing less than 77^{mg} $CaCO_3$ per liter (i. e., 0.0077%), while *S. recurvum*, least sensitive, bears less than 312^{mg}. *S. rubellum* changes its beautiful red to a blue, indicating an alkaline reaction, the more clearly the higher the lime content of the solution.—C. R. B.

Julianiaceae.—Under this name HEMSLEY[41] has established a new family of Mexican plants, known at present to contain two genera (Juliania and Orthopterygium) and five species. Its closest relationships are said to be with the Anacardiaceae and Cupuliferae; but the final judgment of the author places it in linear arrangement between Juglandaceae and Cupuliferae. "The absolute separation of the sexes and the very great diversity of the floral structure of the sexes, associated with pinnate leaves, offers a combination of characters probably without a parallel."—J. M. C.

Fossombronia.—HUMPHREY has described[42] in detail the germination of the spores and the development of the sex organs of a Californian species, *F. longiseta*, the first investigation of any member of the genus since LEITGEB'S, nearly 30 years ago. No striking anomalies appear. No centrosome was observed at any stage of nuclear division; blepharoplasts seem to appear *de novo*, and a *Nebenkörper* likewise, forming the middle piece of the sperm. The spermatids are of the pyramidal form described by IKENO in Marchantia, with no wall between the pair.—C. R. B.

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[39] RIDDLE, LINCOLN W., Contributions to the cytology of the Entomophthoraceae; preliminary communication. Rhodora **8**:67–68. 1906.

[40] PAUL, H., Zur Kalkfeindlichkeitsfrage der Torfmoose. Ber. Deutsch. Bot. Gesells. **24**:148–154. 1906.

[41] HEMSLEY, W. BOTTING, On the Julianiaceae, a new natural order of plants. Abstract. Read before Royal Society, London, June 28, 1906.

[42] HUMPHREY, H. B., The development of *Fossombronia longiseta* Aust. Annals of Botany **20**:83–108. *pls. 5–6.* 1906.

Anatomy of the Araliaceae.—VAN TIEGHEM[43] has published the results of a very extended anatomical study of the Araliaceae as a basis for their classification. He is convinced that he has discovered anatomical characters that are of great service in this way, and he applies them in establishing groups of genera, in making diagnoses of genera more precise, and in clearing up the positions of a number of critical species. The following six new genera are characterized: *Bonnierella, Mesopanax, Plerandropsis, Octotheca, Strobilopanax, Schizomeryta.* —J. M. C.

Germination among palms.—GATIN[44] has published an extended study of germination among palms, having included in his researches 58 species, representing 33 genera. The first and far the larger part of the paper deals with what are called "anatomical" studies, and one conclusion that is reached, among several others, is that the "cotyledon," so far as palms are concerned, is a single leaf and not a phylogenetic coalescence of two leaves. The second part deals with the chemistry of germination.—J. M. C.

Water relations of the coconut.—The anatomy of the root and leaf of this palm, as well as the conditions affecting the entrance and passage of water through the plant, have been investigated by COPELAND.[45] Maximum transpiration is found to favor maximum yield of fruit. Wind and intense sunlight accelerate transpiration. The roots should be abundantly supplied with water, though an excess is injurious. Irrigation is altogether practical.—RAYMOND H. POND.

Fossil roots of Sequoia.—LIGNIER[46] has identified the roots called *Radiculites reticulatus* as those of Sequoia, or of some allied form as Taxodium. The material studied is from the Stephanian of Grand' Croix, and its distinguishing feature is the reticulated cortical parenchyma. Comparing it with roots of similar structure in living plants, the conclusion is reached that it most nearly resembles the structure observed in the root of *Sequoia gigantea.*—J. M. C.

N. Am. Vernonieae.—GLEASON[47] has published a revision of the North American species of Vernonieae. Seventeen genera are characterized, two of which (*Eremosis* and *Orthopappus*) are new. The species number 143, of which 28 are new. The large genus is Vernonia, with 99 species, 25 of which are new; and the new genus Eremosis includes 15 species, 13 of which have heretofore been assigned usually to Vernonia.—J. M. C.

43 VAN TIEGHEM, PH., Recherches anatomiques sur la classification des Araliacées. Ann. Sci. Nat. Bot. IX. 4:1–208. *figs. 54.* 1906.

44 GATIN, C., Recherches sur la germination des palmiers. Ann. Sci. Nat. Bot. IX. 3:191–315. *pls. 11. figs. 58.* 1906.

45 COPELAND, E. B., On the water relations of the coconut palm. Philippine Jour. Sci. 1: 6–57. *pls. 3.* 1906.

46 LIGNIER, O., *Radiculites reticulatus*, radicelle fossile de Séquoinée. Bull. Soc. Bot. France IV. 6:193–201. *figs. 5.* 1906.

47 GLEASON, H. A., A revision of the North American Vernonieae. Bull. N. Y. Bot. Gard. 4:144–243. 1906.

Apical meristems of monocotyl roots.—DAISY G. SCOTT[48] has investigated the root tips of Alisma, Butomus, Vallisneria, Ruppia, Zostera, Naias, Stratiotes, and Limnocharis. Her results support DE BARY'S statement in reference to the roots of monocotyledons in general, namely that there are three distinct groups of initials, one giving rise to calyptrogen, another to dermatogen and periblem, and the third to plerome.—J. M. C.

Megaspores of Lepidostrobus.—Mrs. D. H. SCOTT[49] has found that certain megaspores referred to KIDSTON'S Triletes belong to *Lepidostrobus foliaceus*, heretofore regarded as homosporous. They are peculiar in bearing a conspicuous appendage, said to be suggestive of the so-called "swimming apparatus" of Azolla. Many of these spores were found, and they are spoken of as "fairly common objects."—J. M. C.

N. Am. Hydnaceae.—BANKER[50] has published a revision of the pileate forms of Hydnaceae found in North America north of Panama, and including the adjacent islands. A few resupinate forms are included, but in general they are excluded, awaiting an examination of the Berkeley types. Ten genera are presented, two of them being new (*Leaia* and *Grandinioides*), and of the 63 species 10 are new.—J. M. C.

Fossil germinating spores.—SCOTT[51] has announced the discovery of germinating spores in a sporangium of *Stauropteris Oldhamia*. The discovery is important, for it has been in doubt whether this species should be regarded as a fern or a pteridosperm. The germination is distinctly fern-like, and confirms the anatomical resemblance of this species to the Botryopterideae.—J. M. C.

Apple scab.—LAWRENCE[52] reports further studies of the apple scab in Washington. In a comparative test of the relative effects of the dust spray mixture and the ordinary liquid Bordeaux it was found that the liquid was twelve times as effective as the dust spray. This is in accord with the results secured by CRANDALL[53] in Illinois.—E. MEAD WILCOX.

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48 SCOTT, DAISY G., The apical meristems of the roots of certain aquatic monocotyledons. New Phytol. **5**:119–129. *pl. 9.* 1906.

49 SCOTT, RINA, On the megaspore of *Lepidostrobus foliaceus*. New Phytol. **5**:116–19. *pl. 8. figs. 24–25.* 1906.

50 BANKER, H. J., A contribution to a revision of the North American Hydnaceae. Mem. Torr. Bot. Club **12**: 99–194. 1906.

51 SCOTT, D. H., The occurrence of germinating spores in *Stauropteris Oldhamia*. New Phytol. **5**:170–172. 1906.

52 LAWRENCE, W. H., Apple scab in Eastern Washington. Bull. Wash. Exp. Sta. **75**:1–14. 1906.

53 CRANDALL, C. S., Spraying apples. Relative merits of liquid and dust applications. Bull. Ill. Exp. Sta. **106**:205–242. *pls. 1–9. figs. 1–5.* 1906. Review in BOT. GAZETTE **42**:157. 1906.